LITHOLOGY AND CYCLICITY IN THE DEPOSITION OF THE MIDDLE ORDOVICIAN MCKEE SAND MEMBER OF THE TULIP CREEK FORMATION (SIMPSON GROUP) IN THE TOBOSA BASIN OF SOUTHEAST NEW MEXICO AND WEST TEXAS

A Thesis

by

MICHAEL JOHN BOSCO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 1999

Major Subject: Geology

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ABSTRACT

Lithology and Cyclicity in the Deposition of the Middle Ordovician McKee Sand Member of the Tulip Creek Formation (Simpson Group) in the Tobosa Basin of Southeast New Mexico and West Texas. (August 1999)

Michael John Bosco, B.S., George Mason University

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The lower Paleozoic rocks deposited on the inner craton of North America are characterized by thick sections of carbonate rocks separated by thin units of sandstones and shales. The origins of these sandstones are poorly understood, but it is generally agreed upon that they were deposited in a near shore environment during a relative highstand in a shallow epicontinental sea. One of these sandstones, the McKee Sand, having a maximum thickness of approximately 230 feet in the Tobosa Basin, appears to be abnormally thick to have been deposited during a single sea-level highstand event. Therefore, the McKee was deposited as a result of several smaller progradational highstands and transgressions as opposed to a single higher order highstand event. Changes in quartz sand grain size and percentage of clay and carbonate composition accompanied by sharp breaks and repetition in facies delineate this cyclicity.

The McKee Sand is largely composed of sandstones, muddy sandstones, and sandy mudstones. The sandstones are generally subquartzose to quartzose (50 to 100%), moderately well-sorted and very fine to fine grained. Very fine to medium sand-sized

detrital collophane is sometimes common (<16%), as are fossils, but feldspars in the McKee are rare (<2%) making the McKee sandstones overall quartz arenites. Medium sand to cobble gravel-sized, rounded to well-round, mudstone rock fragments are locally abundant and often deformed.

Four facies can be distinguished in the McKee Sand based on sediment lithology and sedimentary structures. Cyclic breaks in lithology occur above tidal flat or tidal channel facies (facies 3 and 4 respectively) at the maximum flooding surface. Above the maximum flooding surface lies the most basinward facies either the inner shelf facies (facies 1), or more commonly the wave-dominated beach facies (facies 2). In general, a sequence in the McKee Sand consists of the most basinward facies overlain by progressively landward facies. A composite sea-level curve showing this cyclicity can be extrapolated from this information.

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INTRODUCTION

The lower Paleozoic rocks deposited on the inner craton of North America are characterized by thick sections of carbonate rocks separated by thin units of quartzose sandstones and shales that were deposited during a relative highstand (Wilson, 1975). The origins of these sandstones are poorly understood, but it is generally agreed upon that they were deposited in a near shore environment in a shallow epicontinental sea. One of these quartzose sandstones, the McKee Sand, was first recognized as the basal member of the Tulip Creek Formation in the carbonate dominated Simpson Group of West Texas by the West Texas Geological Society in 1941 (Cole et al., 1942). Until the present day, this is the only published material specifically on the McKee Sand. Two other basal quartzose sandstones are recognized in other formations of the Simpson Group, the Connell Sand member of the Joins Formation (Schweers, 1949), and the Waddell Sand member of the McLish Formation (Cole et al., 1942). This study will not examine the Connell Sand or the Waddell Sand and no specific research has since been published.

The McKee Sand is the basal member of the Tulip Creek Formation of the Simpson Group and is composed of quartzose sandstones with a complex mineralogy of matrix and cements separated by and intermixed with sandy mudstones and carbonates. Having a maximum thickness of approximately 230 feet, the McKee Sand divides the

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remaining Tulip Creek Formation above from the McLish Formation below. This sandstone appears to be abnormally thick to have been deposited during a single sea-level highstand event on the cratonic interior in an area of little relief.

The purpose of this study is to correlate sea-level fluctuations with the lithology of the McKee Sand in the Tobosa Basin (Figure 1). Materials examined include conventional cores for determination of bedding characteristics, core samples for petrological and grain size analysis, as well as other information. In addition, this study will attempt to characterize the petrology and environment of deposition of the McKee Sand.

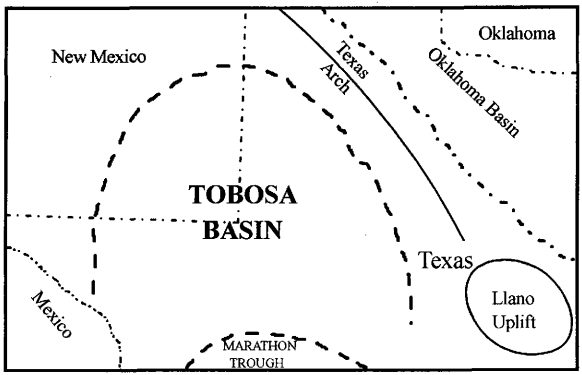

Fig. 1. Map of the Southwestern United States showing the approximate location of the Tobosa Basin, and other major features present in the early to middle Paleozoic (modified after Johnson et al., 1988).

GEOLOGIC SETTING

Tectonic History

The Tobosa Basin was a narrow, minor cratonic basin that occupied West Texas and Southeast New Mexico during the early Paleozoic, in the present position of the Permian Basin. The low lying landmass of the Texas Arch (or Texas Peninsula) separated the Tobosa Basin from the larger Oklahoma Basin to the Northeast.

The Tobosa Basin began to form sometime from the early Proterozoic to mid-Late Cambrian (Sloss, 1988). During this time, the North American continent was situated about 25° south of the equator and rotated roughly 45° clockwise from its present position (Scotese and McKerrow, 1990). During the mid-Late Cambrian to Early Ordovician Sauk III subsequence (Figure 2), the Tobosa Basin went through a minor period of subsidence (Figure 3a) as a result of the deposition of the Ellenburger Group (Sloss, 1988). Before the end of the Early Ordovician, the craton rapidly emerged above base level, exposing the carbonate-dominant Ellenburger Group and subaerially producing a karst surface.

At the beginning of the Middle Ordovician Tippecanoe I subsequence, the Simpson Group was deposited unconformably on top of the Ellenburger Group, causing irregular thickening of the Joins Formation, the bottom formation of the Simpson Group. Following the Joins Formation's deposition, the Oil Creek, McLish, Tulip Creek, and Bromide Formations were deposited respectively, completing Simpson deposition. This deposition was concurrent with a low to moderate rate of flexural subsidence (Figure 3b).

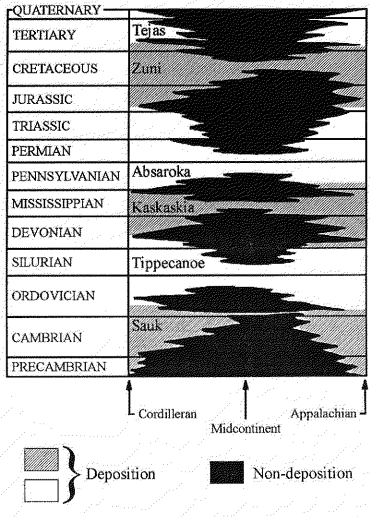

Fig. 2. Time stratigraphic relationship of the six major sequences in the Midcontinent of North America (modified after Sloss, 1963).

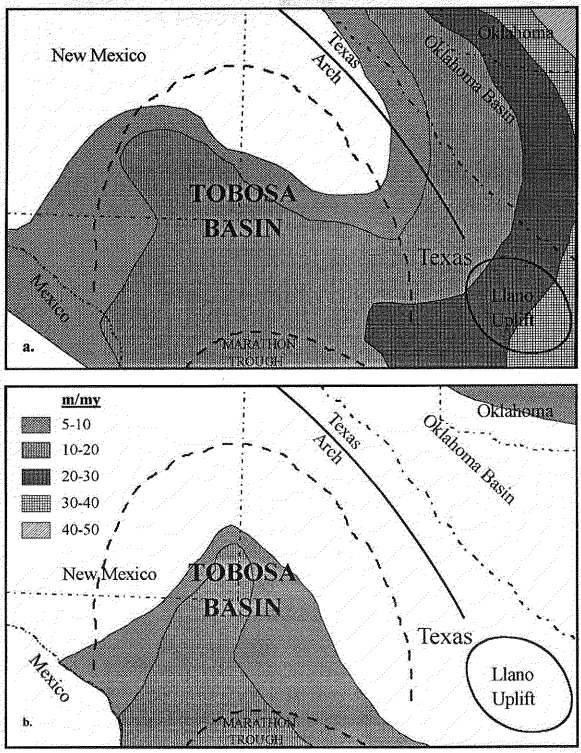

Fig. 3. Map of net subsidence rate in the Tobosa Basin and southwestern Oklahoma Basin during the (a) latest Proterozoic to Early Ordovician Sauk sequence, and (b) the Middle Ordovician to Early Devonian Tippecanoe sequence (modified after Sloss, 1988).

The McKee Sand, the basal member of the Tulip Creek Formation, was deposited as part of the Tippecanoe I sequence (Sloss ,1988). The top of the Tippecanoe I subsequence is marked by a disconformity, probably related to the episode of Gondwana continental glaciation of the latest Ordovician to earliest Silurian Time (Sloss, 1988).

After the Simpson Group was deposited, the Early Silurian to Early Devonian Tippecanoe II subsequence in the Tobosa Basin was deposited under conditions in which subsidence rates were greater than sedimentation rates, thus leading to deposition of deep water silty and marly carbonates. At the end of the Tippecanoe II subsequence, the Tobosa Basin, along with most of North America, was subaerially exposed as the results of sporadic episodes of regressions, which reached a climax in the earliest Devonian.

During deposition of the mid-Early Devonian to Late Mississippian Kaskakia Sequence, accumulation rates of sediment were low for this basin, especially compared to times before and after in the Tobosa Basins history. However, by Mississippian time, the Tobosa Basin began to differentially subside, creating the precursor to the Central Basin Platform.

During the latest Mississippian to Early Permian Absaroka I subsequence, a positive north-south trending belt, the central basin platform, arose from the axis of the Tobosa Basin, separating the Delaware Basin in the west from the Midland Basins in the east (Hills, 1972). The creation of the Central Basin Platform had sufficient vertical movement to expose basement rock. The collective basins known as the Permian Basin came into existence at this time.

Tectonic stability during the Late Pennsylvanian and Permian led to the eventual filling of the shallower Midland Basin and then, by the end of the Middle to Late Permian Absoroka II sequence, the deeper Delaware Basin. Erosion from areas of positive relief provided sediment for the filling of these basins (Dean and Anderson, 1982).

After this period of tectonic quiescence, minor and transient downwarping occurred during the Triassic to Early Jurassic Arsaroka III subsequence in the Permian Basin. This led to deposition of red beds (Sloss, 1988).

The latest occurrence of tectonic activity in the Tobosa Basin was during the late Mesozoic to early Cenozoic Laramide Orogeny. During this period, mild tectonic stresses caused the western end of the Tobosa Basin to be uplifted slightly and tilted eastward (Hills, 1963; McKee, 1967). The Tobosa Basin has experienced little tectonic activity since the Laramide Orogeny.

Stratigraphy

The McKee Sand is the basal member of the Tulip Creek Formation of the Middle Ordovician Simpson Group in the Tobosa Basin (Figure 4). The term 'member' is loosely used here, as no members in the Tulip Creek Formation have been formally recognized. This distinction of the McKee Sand is due to its importance as an oil producing unit in the Tobosa Basin (Cole et al., 1942).

The Simpson Group is unconformably bounded below by a karst surface atop the Ellenburger Group, and unconformably bounded above by the Montoya Limestone, Pennsylvanian strata, or Permian, strata where pre-Permian or Permian erosion has

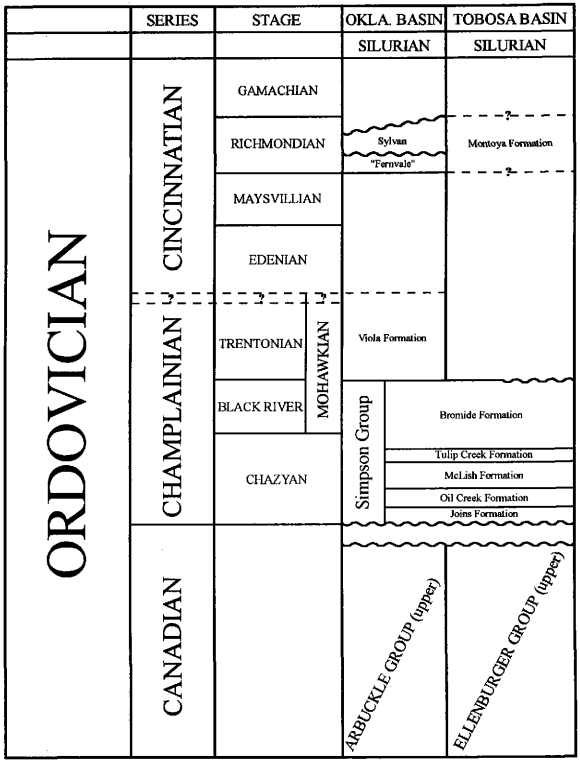

Fig. 4. Generalized standard Ordovician section of the Tobosa Basin and Oklahoma Basin (modified after Twenhofel, 1954).

removed overlying material (Colton, 1957). Five formations belong to the Simpson Group (bottom to top): the Joins, Oil Creek, McLish, Tulip Creek, and Bromide. In addition to the McKee Sand, other basal quartzose sands are formally recognized in two other formations of the carbonate-dominated Simpson Group: the Connell Sand member of the Joins Formation (Schweers, 1949) and the Waddell Sand member of the McLish Formation (Cole et al., 1942).

The formations of the Simpson Group have the same names and similar lithologies on the other side of the Texas Peninsula and into the Oklahoma Basin. However, the member names are restricted to use in the Tobosa Basin. Lithologies and electric log signatures of the Simpson Group are sometimes so similar in comparison on different sides of the Texas Peninsula that they exhibit almost mirror image qualities (Suhm, 1997). The basal sand of the Tulip Creek Formation in the Oklahoma Basin correlative to the McKee Sand is sometimes referred to as the "Wilcox" Sand (Decker and Merritt, 1931). In the Oklahoma Basin, the bottom of the Simpson Group is unconformably bounded by the Arbuckle Group and the top of the Simpson Group is conformably bounded by the Viola Formation. In central Kansas, and north through the North American Craton, the Simpson group changes to its lateral equivalent, the St. Peter Sandstone.

Thickness of the McKee Sand is variable, with a maximum published thickness of approximately 230 feet (Colton, 1957). It is composed of clean, muddy, and calcareous quartzose sandstones interbedded with mudstones and carbonates. The upper and lower contacts of the McKee are defined by the lack of any significant quartz-rich sandstones.

Due to only a small quantity of reliable published data, the areal extent of the McKee is unknown.

The Problem of the McKee Sand

According to Dapples (1955), the sands of the Simpson Group were deposited as a result of a transgressing series of unbroken shorelines on the inner craton. However, the maximum published thickness of the McKee Sand is approximately 230 feet (Colton, 1957). Previous work has shown that shallow marine sand bodies deposited during a single sea-level change cycle are generally very thin in nature (Field, 1980). A sand of this thickness could not have been deposited during a single sea-level change cycle (Figure 5) in an area of little relief such as the cratonic interior. Therefore, multiple successions of sea-level changes in the Middle Ordovician during a relative highstand is likely to be the mechanism that created a sand package of this thickness. However, this has yet to be confirmed.

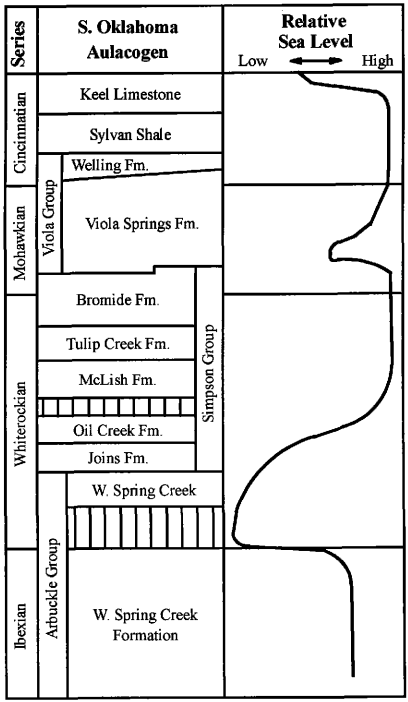

Fig. 5. Stratigraphic section for the southern Oklahoma Basin and sea-level curve for Ordovician of North America (modified after Finney, 1986, Derby et al., 1991, and Finney, 1997).

METHODS

Depositional environments of the McKee Sand were determined by the examination and analysis of eight conventional cores from five different fields situated on the Central Basin Platform (Figure 6). These cores were slabbed using a water-cooled brick saw. The slabbed cores were then described for lithology and sedimentary structures, photographed, and sampled. Two types of samples were taken: rock billets to be cut into thin sections, and loose rock samples placed in 15-ml vials for grain size and electron microprobe analysis. Samples were taken over a variable interval due to the frequent occurrence of missing section. The ARCO University A-11-5 core was not sampled due to frequently mislabeled depths on the core boxes. The measurement of grain shape was not taken into consideration due to the sand's generally well-rounded nature as well as a localized abundance of primary quartz overgrowths.

Vial samples were prepared for grain size analysis using the following procedure. First, the samples were removed from their respective vials, and placed into 250-ml plastic beakers. When needed, the samples were disaggregated with a mortar and pestle until they were smaller than pea gravel size. Next, the samples were treated with 37 percent hydrochloric acid solution, and after soaking overnight, deionized water was added to dilute the acid. After settling, the dilute acid was carefully poured-off without allowing any sand to escape. More deionized water was added to the beakers and these steps were repeated until the sample had a neutral pH. Next, as much of the water as possible was poured-off without allowing any sand to escape and the samples were

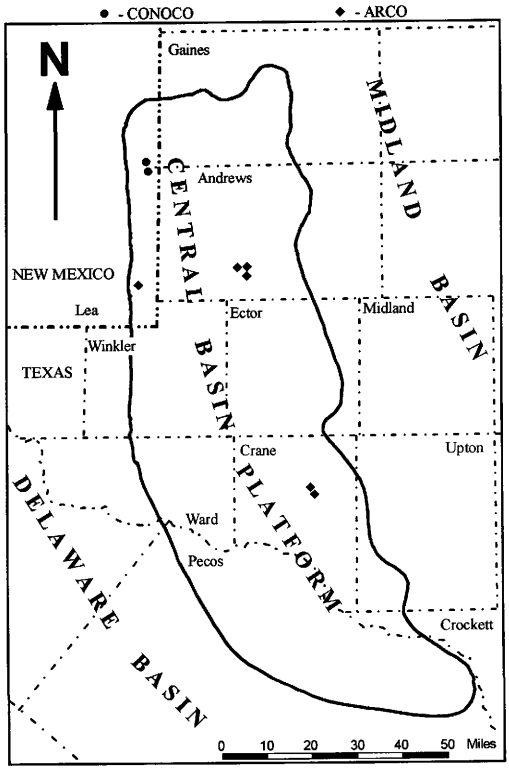

Fig. 6. Political map of study area showing core locations and commonly used Permian Basin physiographic features.

treated with 48 percent hydrofluoric acid solution. The samples were soaked for approximately 30 minutes in this solution and then diluted with deionized water, allowed to settle, and poured off repeatedly until a neutral pH was reached as described above. Excessively dirty samples required a repeated or an extended hydrofluoric acid treatment until they took on a clean snow white appearance. Next, the samples were wet sieved with a 63-μm sieve, the fine fraction was discarded, and the coarse fraction was dried overnight in an oven at 70° C. The dried samples were then split using a standard splitter until an appropriate amount of sample was collected for analysis. The split was then added to glycerin, mounted on microscope glass and topped with a glass cover slip. Any excess sample was saved.

Long-axis grain size measurements were made of the sand grains in the glycerin mount using Image Pro software on an IBM compatible computer hooked up to a petrographic microscope with a digital video camera. One hundred monocrystalline quartz grains per sample were measured and the grain size data were exported from the Image Pro software to a spreadsheet format. Using Lotus 1-2-3, the grain size data were sorted, and a mean, median, and standard deviation for each sample was calculated. Maximum entropy histograms (Full, Ehrlich, and Kennedy, 1984) were produced for all 129 samples.

Mineralogic composition was determined using a petrographic microscope and an electron microprobe. Standard point counts were done on 91 blue-epoxied, vacuum-impregnated unpolished thin sections. Detrital minerals, authigenic minerals, and pore spaces were counted until a count of 100 monocrystalline quartz grains per thin

section was achieved. Of these categories, detrital minerals and authigenic minerals were divided into several compositional sub-categories.

An electron microprobe was used on two samples from the Conoco Warren McKee #27 core to aid in identification of unknown minerals and to take scanning electron microscope (SEM) images. Samples chosen for electron microprobe mineral identification were clusters of sand grains. First, these samples were soaked in epoxy so that the epoxy could penetrate the pore spaces. Next, they were place in a microprobe epoxy mount, covered with additional epoxy, and allowed to harden for 24 hours. The mount was ground down with 320 grit sandpaper until a reasonable amount of sample was showing through the epoxy and the sample was flush with the surface. Next, 600 and 1200 grit sandpaper was used, followed by polishing with 3.0 and 0.3 μm alumina until the sample was extremely smooth. These samples needed to be very finely polished in order to minimize X-ray and optical scattering. Therefore, these were the samples in which energy dispersive spectrometry (EDS), wavelength dispersive spectrometry (WDS), and cathodoluminescence were run. Next, the samples were carbon coated, and a drop of carbon paint was placed near the edge of the polished section to ensure electrical conductivity.

Samples that were chip-shaped and had a low and horizontal profile were chosen for SEM imagery using the microprobe's secondary electron (SE) detector. These samples were attached to grain mounts with carbon tape, and then gold-sputtered to ensure their electrical conductivity.

Finally, one sample of red shale from the ARCO University C-11-3 core was run on an x-ray diffractometer to determine its clay content. Standard processing for clay mineral identification was not performed due to the samples apparent homogeneity. Also, data on the clay mineralogy of the McKee Sand was available making a detailed clay mineralogy analysis unnecessary.

CHARACTERISTICS OF THE MCKEE SAND

Lithology

The McKee Sand is largely composed of sandstones, muddy sandstones, and sandy mudstones. The sandstones are generally subquartzose to quartzose (50 to 100%), moderately well-sorted and very fine to fine grained, and the detrital grains are subangular to rounded when quartz overgrowths are not present. Some well-rounded medium quartz sand grains are also present. Very fine to medium sand-sized detrital collophane is sometimes common (<16%), as are fossils, but feldspars in the McKee are rare (<2%) making the McKee sandstones overall quartz arenites. Medium sand to cobble gravel-sized, rounded to well-round, mudstone rock fragments are locally abundant and often deformed.

The detrital clays in the McKee have a mixed mineralogical composition. Illite tends to be the predominant detrital and authigenic species, but glauconite, berthierine, odinite, kaolinite, smectite, and chlorite clays, along with hematite and micrite, may also be present.

The authigenic cements in the McKee Sand are carbonates, clays, and quartz. Pore-filling carbonate cements occur in the forms of crystalline calcite, dolomite, ankerite, and siderite. They can also occur as recrystallized micrite and recrystallized fossils. Authigenic clays occur as grain-lining cements.

Finally, the McKee exhibits a wide range of colors, and a variable, but generally high, degree of bioturbation. Green sandstones tend to be dominated by glauconite and

illite clay, and the lighter greens, which have less clay, are the most friable. Brown and yellow sandstones tend to have more authigenic quartz cement and are generally clay free. Gray sandstones have abundant carbonate cement and micritic mud, while red sandstones have more hematitic clay. Bioturbation tends to mix and mottle these colors in a wide range of proportions.

Facies

Four facies can be distinguished in the McKee Sand based on sediment lithology and sedimentary structures.

Facies 1

Facies 1 is composed of very thin to thick bedded, bioturbated, planar-parallel and wavy non-parallel laminated, grayish green to yellow, non-fossiliferous, very fine to fine and muddy quartzose sandstones (Figure 7). It is distinguished from other facies by its abundant detrital clay content; its considerably lesser and smaller (generally sand size) rock fragments; the rare occurrence of fossils; and the absence of carbonates, cross-laminae, flasers, mudcracks, and interbedding of mudstone and sandstone (Figures 8 and 9). The mean detrital grain sizes of the sandstones range from 103 to 169 μm, and their standard deviations range from 33 to 115 μm. When plotted on a maximum entropy histogram, the grain size data show either relatively even distributions of sizes or negative skewing (Figure 10). Facies thickness ranges from 3 to 18 feet.

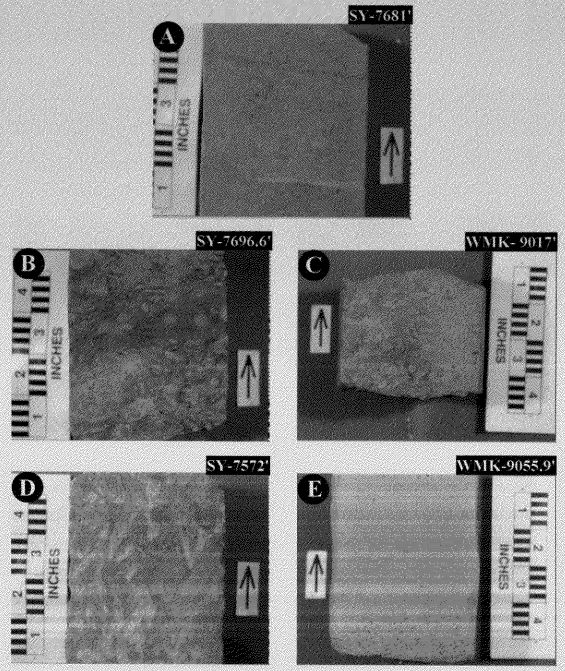

Fig. 7. Core photos showing examples of types of bedding and varying degrees of bioturbation in facies 1: (A) parallel planar laminae, (B) non-parallel wavy laminae, (C) mottled bedding, (D) burrowed bedding, (E) massive bedding.

Facies	Primary Structures					Secondary Structures		Grain Size (μm)		
	wavy parallel	wavy non-parallel	planar parallel	cross-lamination	flasers	mud cracks	bioturbation	# of samples	range of mean	range of stnd. dev.
One (inner shelf)		●	●				■	18	103-169	33-115
Two (beach/barrier)	☒	☒	☒	☒	○		■	53	113-309	39-144
Three (tidal flat)	☒	☒	☒	●	■	☒	■	48	102-319	30-154
Four (tidal channel)	☒	☒	☒	☒			■	10	89-114	18-60

Facies	Detrital Composition					Authigenic Composition			
	quartz	rock fragments	clay	coliophane	fossils	quartz	clay	carbonate	porosity
One (inner shelf)	■	●	■	●	○	○	○	○	■
Two (beach/barrier)	■	☒	☒	☒	●	●	☒	■	☒
Three (tidal flat)	■	■	■	☒	■	○	☒	■	●
Four (tidal channel)	■	○	●	●	☒	☒	☒	●	●

■ abundant (>25%)
☒ common (10 to 25%)
● occasional (2 to 10%)
○ rare (<2%)

Fig. 8. Table displaying characteristics of the four facies of the McKee Sand.

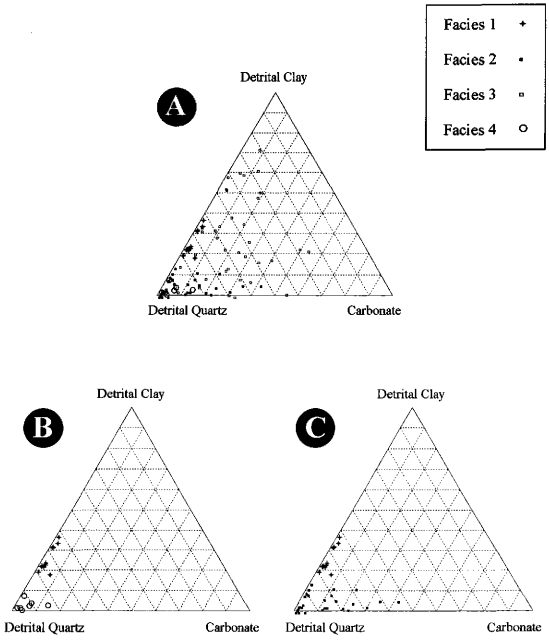

Fig. 9. Ternary diagrams displaying the compositions of the McKee Sand: (A) all four facies plotted, (B) only facies 1 and 4 plotted, (C) only facies 1 and 2 plotted.

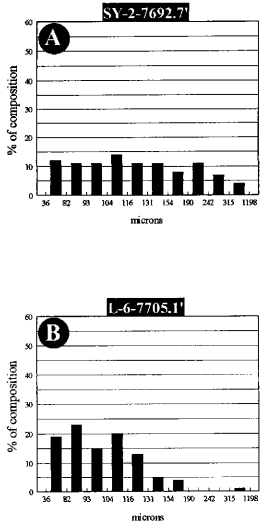

Fig. 10. Typical maximum entropy histograms for facies 1 showing (A) a relatively even distribution of grain sizes and, (B) grain size distribution with negative skewing.

The planar and wavy laminae of facies 1 are often 0.1 to 2.0 cm thick when present, but are commonly convoluted and broken by burrows. The laminae are bioturbated to varying degrees: in some beds, they are visible despite burrowing (Figures 7a and b), in others, they are mottled (Figure 7c), in others, they are burrowed (Figure 7d), and in others, they are obliterated and the beds are massive (Figure 7e).

The detrital composition of facies 1 is primarily dominated by quartz (62 to 80% of detrital composition), and detrital clay (20 to 38% of detrital composition), and lesser amounts of collophane (<9% of detrital composition) and rock fragments (<10% of detrital composition) (Figure 11). When they are small enough to be identifiable in thin section, the rock fragments are composed of rounded medium sand to coarse sand-sized gray to black mudstone and appear to contain a high concentration of collophane (Figures 11a and b).

The authigenic cement content of facies 1 is the least of all four facies (Figure 12). Quartz (Figure 12c and d) and carbonates (Figures 12e and f) are rare (<1% of total composition), and authigenic clays (Figures 12a and b) occur only occasionally (<2% of total composition). Pre-Simpson from post-Simpson authigenic quartz overgrowths were often difficult to distinguish due to the presence of rounded quartz overgrowths (Figure 13). Porosities are consequently the highest for this facies (1 to 25% of total composition) and it is generally the most friable of all four facies.

Facies 2

Facies 2 is composed of very thin to medium bedded, bioturbated, planar-, wavy-, and cross-laminated, yellowish-brown and yellowish-gray, very fine to fine quartzose

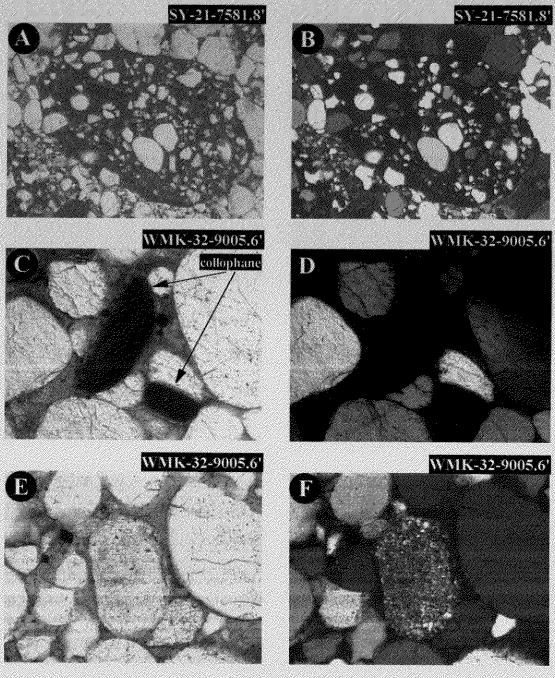

Fig. 11. Thin section photos showing examples of detrital components present in the McKee Sand: (A) mudstone rock fragment in plane light and (B) under crossed nicols, (C) collophane grains in plane light and (D) under crossed nicols , (E) monocrystalline quartz grains with rare polycrystalline quartz grain in center in plane light and (F) under crossed nicols.

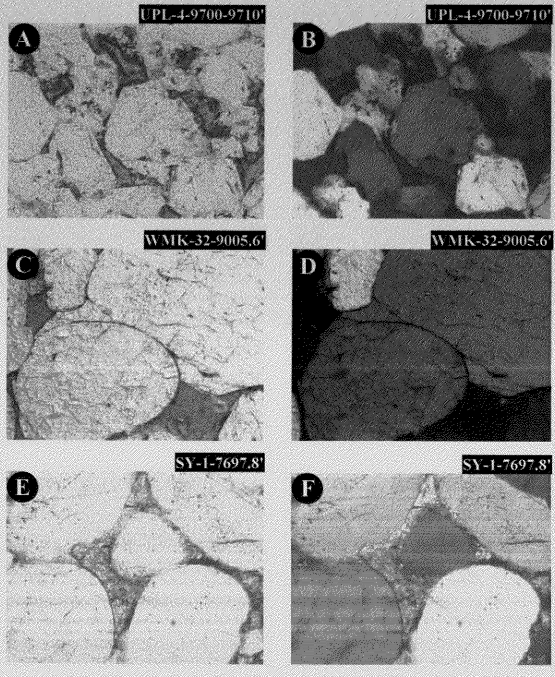

Fig. 12. Thin section photos showing examples of authigenic components present in the McKee Sand: (A) authigenic clay lining pores and quartz overgrowths in plane light and (B) under crossed nicols, (C) quartz overgrowths in plane light and (D) under crossed nicols, (E) pore filling carbonate in plane light and (F) under crossed nicols.

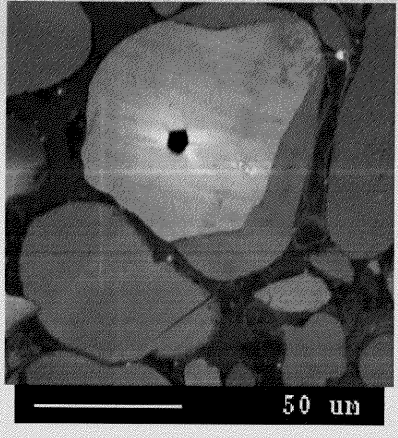

Fig. 13. Image of quartz grain under cathodoluminescence showing rounded quartz overgrowths along with zircon inclusion.

sandstones (Figure 14). It is distinguished from other facies by its abundance of carbonates; the common presence of rock fragments and detrital clay; the occasional presence of fossils; the rare occurrence of flasers; and the absence of mudcracks and interbedded mudstone and sandstone. The mean detrital grain sizes of the sandstones range from 113 to 309 μm, and their standard deviations range from 39 to 144 μm. Facies 2 is generally coarser and more poorly sorted then facies 1 and 4, and similar in grain size and sorting to facies 3. When plotted on a maximum entropy histogram, the grain size data usually show either bimodal distribution of sizes or positive skewing (Figure 15). Facies thickness ranges of 0.5 to 20 feet.

Facies 2 is the most bioturbated facies and is usually mottled to burrowed, when they are visible, its planar, wavy, and cross-laminae are 0.1 to 3.0 cm thick. Once again, the laminae are bioturbated to varying degrees: in some beds, they are visible despite burrowing (Figures 14a and b), in others, they are mottled (Figure 14c), in others, they are burrowed (Figure 14d), and in others, they are obliterated and the beds are massive (Figure 14e).

The detrital composition of Facies 2 is primarily dominated by quartz (79 to 100% of detrital composition), with lesser amounts of detrital clay (<15% of detrital composition), rock fragments (<15% of detrital composition) and collophane (<12% of detrital composition). The rock fragments are composed of rounded, medium sand to cobble sized, gray to black mudstone.

The authigenic composition of facies 2 is dominated by carbonates (<39% of total composition), with lesser amounts of authigenic clay (<12% of total composition) and

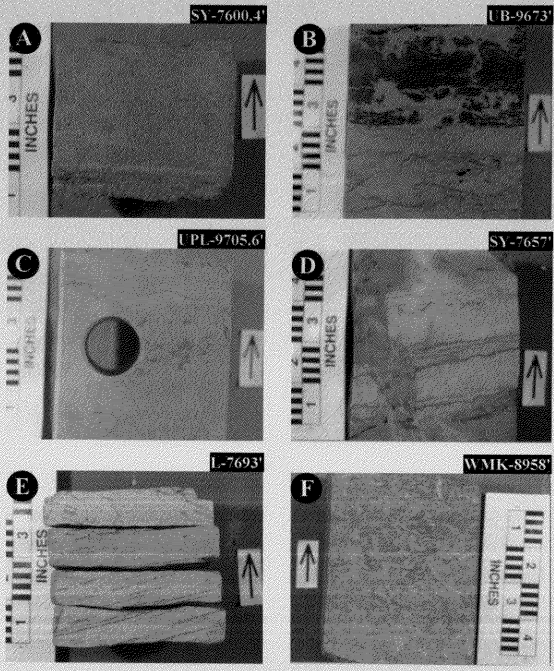

Fig. 14. Core photos showing examples of types of bedding and varying degrees of bioturbation in facies 2: (A) parallel planar laminae, (B) non-parallel wavy laminae, (C) parallel wavy laminae, (D) flaser laminae with cross-cutting burrow, (E) cross-lamination, (F) mottled bedding, (G) burrowed bedding, (H) burrowed bedding with an escape burrow, (I) massive bedding.

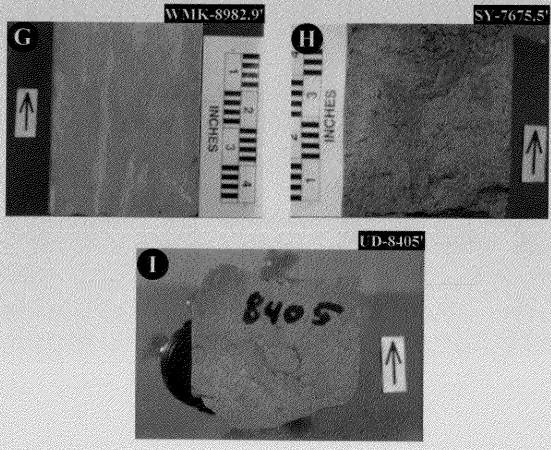

Fig. 14. (continued)

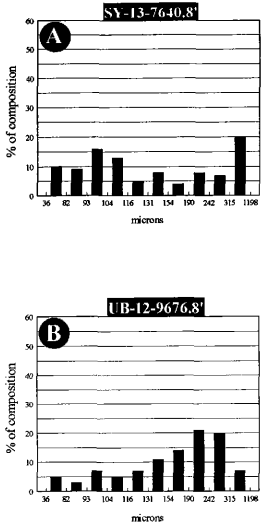

Fig. 15. Typical maximum entropy histograms for facies 2 showing (A) a bimodal grain size distribution, and (B) grain size distribution with positive skewing.

quartz (<9 % of total composition) (Figure 16). Porosities are the second highest for this facies (0 to 21%).

Facies 3

Facies 3 is composed of very thin to medium bedded, bioturbated, planar-, wavy-, and flaser-laminated, fossiliferous, green, gray, red and black, very fine to medium and muddy quartzose sandstones and sandy mudstones with occasional cross-bedding, mudcracks, and dark gray, rounded, medium sand to cobble gravel sized mudstone rock fragments (Figure 17). It is distinguished from other facies by its abundant detrital clay, rock fragments, carbonates, fossils, flasers, and interbedded mudstone and sandstone; and the common presence of mudcracks. The mean detrital grain size of the sandstones range from 102 to 319 μm and their standard deviations range from 30 to 154 μm. When plotted on a maximum entropy histogram, the grain size data usually show either bimodal distribution of sizes or positively skewing (Figure 18). Facies thickness ranges from 0.4 to 13 feet.

The planar, wavy, and cross-laminae of facies 3 are often 0.1 to 3.0 cm thick when present, but are commonly convoluted and broken by burrows. The laminae are bioturbated to varying degrees: in some beds, they are visible despite burrowing (Figures 17a and b), in others, they are mottled (Figure 17c), in others, they are burrowed (Figure 17d), and in others, they are obliterated and the beds are massive (Figure 17e). Mudcracks, when visible, are filled with clean, very rounded, medium, quartzose sand. The thin nature of bedding of very different lithologies combined with burrows greater in

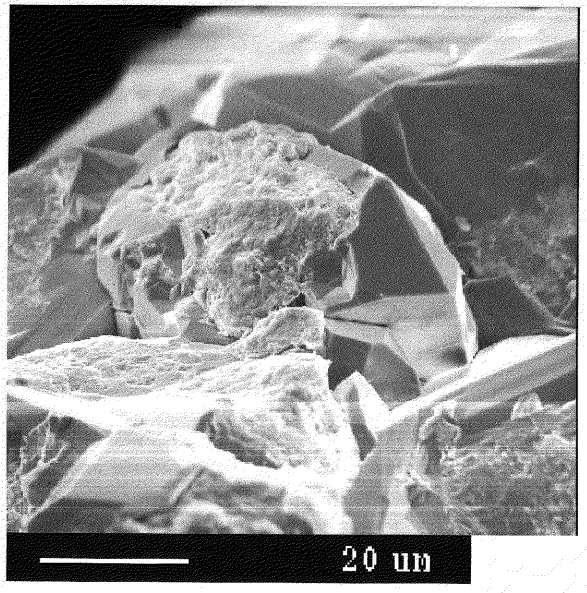

Fig. 16. SEM image of quartz overgrowth from the Warren McKee #27 core at a depth of 8955.3 ft. (sample WMK-12).

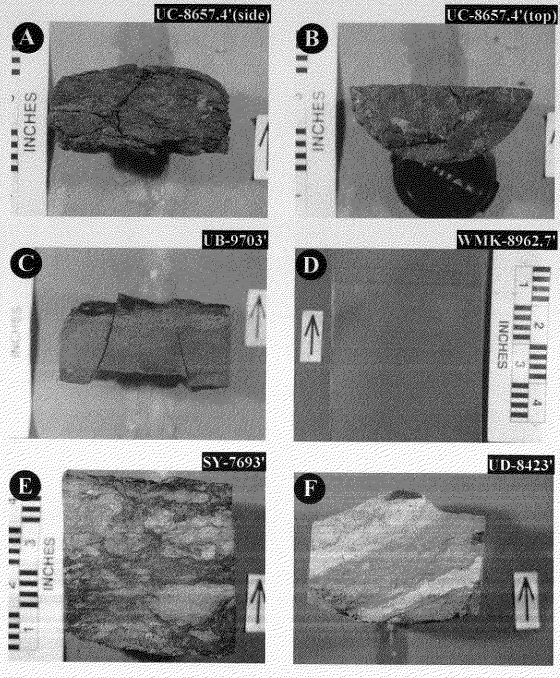

Fig. 17. Core photos showing examples of types of bedding, sedimentary structures, and varying degrees of bioturbation in facies 3: (A) mudcracks (side view), (B) mudcracks (top view), (C) sand stringer, (D) parallel planar laminae, (E) non-parallel wavy laminae, (F) parallel wavy laminae, (G) flaser laminae, (H) cross-lamination, (I) mottled bedding, (J) mottled bedding, (K) burrowed bedding, (L) massive bedding.

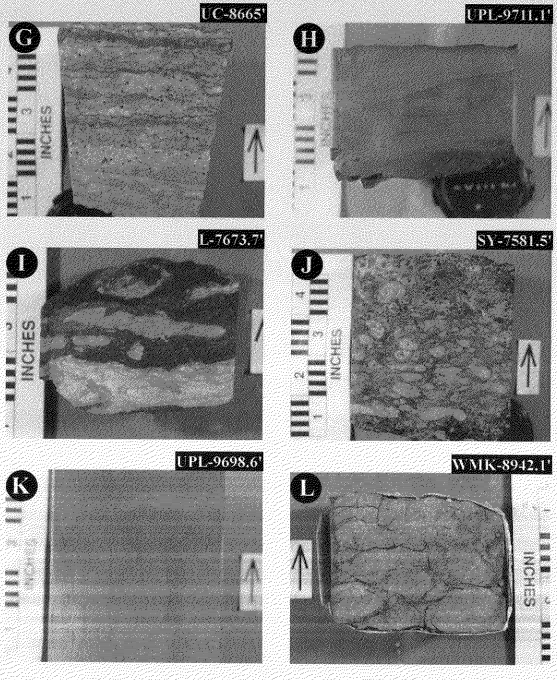

Fig. 17. (continued)

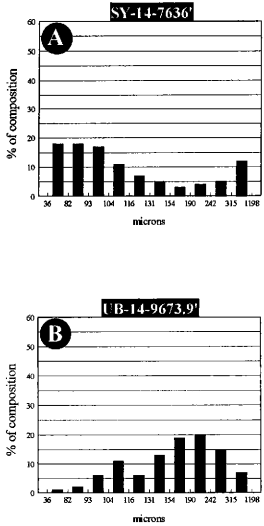

Fig. 18. Typical maximum entropy histograms for facies 3 showing (A) a bimodal grain size distribution, and (B) grain size distribution with positive skewing.

length then individual beds in this facies, makes composition unreliable as being indicative of this facies.

The detrital composition of facies 3 is primarily dominated by quartz (21 to 93% of detrital composition), detrital clay (<74% of detrital composition), and rock fragments (<40% detrital composition), and lesser amounts of collophane (<16% of detrital composition). This facies has the largest amount of rock fragments seen during core description and in thin section (Figures 11a and b). In addition, this facies tends to contain the highest concentration of collophane pellets per sample.

The authigenic cement content of facies 3 is dominated by carbonates (<50% of total composition), and authigenic clay (<13% of total composition), with lesser amounts of quartz (<2% of total composition). In general, the lower the detrital clay content, the higher the carbonate content. Porosities are the lowest for this facies (0 to 9%). Low porosities may be due to its mud and carbonate content and apparently it is often friable.

Facies 4

Facies 4 is composed of very thin to thin bedded, bioturbated, planar-parallel, wavy-, and cross-laminated, yellowish brown, very fine quartzose sandstones and occasional interlaminated green to brown mudstones (Figure 19). It is distinguished from other facies by its common presence of fossils; the occasional presence of detrital clay, carbonates, and interbedded mudstone and sandstone; the rare occurrence of rock fragments; and the absence of flasers and mudcracks. The mean detrital grain sizes of the sandstones range from 89 to 114 μm, and their standard deviations range from 18 to 60 μm. Of all the facies, this is the cleanest, finest, and best sorted. When plotted on a

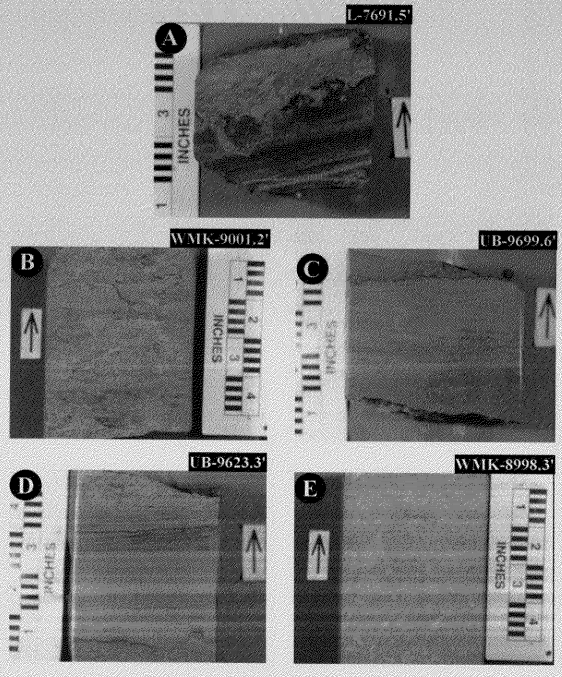

Fig. 19. Core photos showing examples of types of bedding and varying degrees of bioturbation in facies 4: (A) parallel planar laminae, (B) non-parallel wavy laminae, (C) parallel wavy laminae, (D) cross-laminaed, (E) mottled bedding.

maximum entropy histogram, the grain size data show negative skewing (Figure 20). Facies thickness ranges from 1 to 4.5 feet.

The planar-, wavy-, and cross-laminae of facies 4 are often 0.1 to 1.0 cm thick when present and are commonly convoluted and broken by burrows. The laminae are bioturbated to varying degrees: in some beds, they are visible despite burrowing (Figures 19a and b), in others, they are mottled (Figure 19c), in others, they are burrowed (Figure 19d), and in others, they are obliterated and the beds are massive (Figure 19e).

The detrital composition of Facies 4 is primarily dominated by quartz (89 to 98% of detrital composition), and lesser amounts of detrital clay (2 to 8% of detrital composition) and collophane (<7% of detrital composition).

The authigenic composition of facies 4 is dominated by quartz (<12% of total composition) and authigenic clays (<13% of total composition), and lesser amounts of carbonates (<10% of total composition) (Figure 21). Microprobe EDS analysis of an authigenic clay crystal from this facies revealed it to be illite (Figure 21b). Porosities are low to moderate for this facies (2 to 10%) due to the high authigenic clay content.

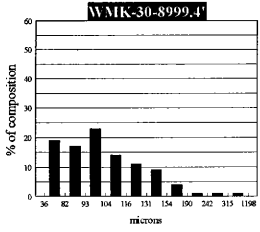

Fig. 20. Typical maximum entropy histogram for facies 4 showing grain size distribution with negative skewing.

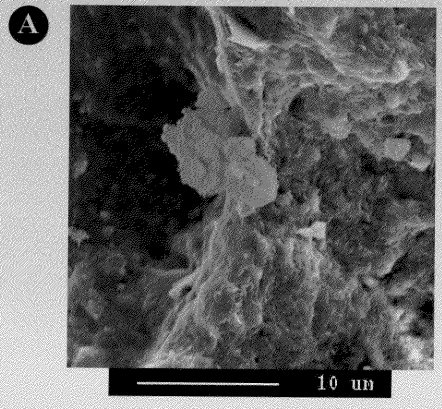

Fig. 21. (A) Image of authigenic clay grain in facies 4 from sample WMK-5 along with (B) the grains EDS spectra.

INTERPRETATION

Depositional Environment

The McKee Sand is a cyclic transgressional and highstand progradational inner shelf, beach, and tidal flat complex that was deposited in an overall restricted shallow marine shelf environment. Cyclic breaks in lithology occur above tidal flat or tidal channel facies (facies 3 and 4 respectively) at the maximum flooding surface (Figure 22). Above the maximum flooding surface lies the most basinward facies either the inner shelf facies (facies 1), or more commonly the wave-dominated beach facies (facies 2). A composite sea-level curve showing this cyclicity can be extrapolated from this information.

Facies 1 is likely to have been deposited in an inner shelf environment as is evident from its moderate mud content, low carbonate content, and finer grain size relative to other facies. The occasional occurrence of mudstone rock fragments are likely to have been the result of storm deposits (Stride et al., 1982). The common occurrence of green and presumably glauconitic clay is restricted to a marine continental shelf environment (Porrenga, 1967). Glauconite is primarily formed in marine areas with low sedimentation rates and in the presence of some organic activity. Modern day conditions analogous to this exist in the Celtic Sea on the continental shelf of southwest England (George and Murray, 1977). However, the sediments in the Celtic Sea are considerably more fossil- and carbonate-rich.

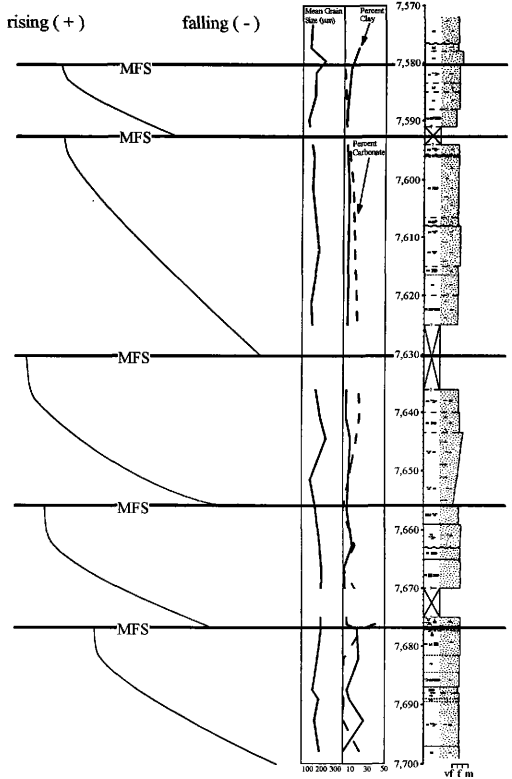

Fig. 22. Maximum flooding surfaces and sea-level curve extrapolated from the ARCO State Y-4 core.

Facies 2 is likely to have been deposited in a wave-dominated beach or nearshore environment, as is evident from the low mud content, high carbonate content, and cross-lamination. Modern day conditions such as this exist in Sapelo Island, Georgia (Howard, 1969). The presence of mudstone rock fragments and the rare occurrence of flasers suggest a tidal influence, and hence a mesotidal coastal environment (Klein, G. deV., 1977).

Facies 3 was deposited in a tidal flat, as is evident from mudcracks, interbedded mudstones and sandstones, flasers, and high fossil content. Modern day conditions analogous to this exist in the tidal flat of Mont Saint-Michel Bay, France (Larsonner, 1975). Collophane, which is also common in situ as well as in mudstone rock fragments in this facies, has been suggested to be indicative of high organic productivity relative to sedimentation rate in a shallow marine environment (Cook, 1976). Mudstone rock fragments in other facies appear to contain a high amount of collophane (Figure 11a and b). Therefore, it is reasonable to assume that their origin is from facies 3.

Facies 4 is likely to have been deposited in a tidal channel environment as is evident from the very fine sand size with a high degree of sorting, high fossil content, bed thickness, and lack of detrital mud, as well as its intimate association with facies 3. Lateral accretion of point bars in tidal channels is likely to have been the mechanism for creation of a sand of this nature (Weimer et al., 1982). The lack of mudstone rock fragments in this facies, may be attributed to their disintegration through abrasion due to high transport velocities in this tidal channel environment. Also, this would explain the lack of mud and high degree of sorting in the facies.

Stratigraphic Sequence

The vertical succession of facies in a section of the CONOCO Warren McKee #27 core (Figure 23) is representative of an ideal stratigraphic sequence observed in the study of the McKee Sand. An ideal sequence consists of facies 1, bounded below by facies 3 or 4, overlain by facies 2, and then followed by either facies 3 or 4. Facies 1 is part of the transgressive systems tract. Facies 2 may also be part of the transgressive systems tract, when it is bounded below by facies 1. However, when facies 1 is not present, facies 2 solely represents the transgressive systems tract. Facies 3 and 4 represent the highstand systems tract. In general, a sequence in the McKee Sand consists of the most basinward facies overlain by progressively landward facies.

Depositional History

Immediately after deposition of the McKee Sand, if not during, major bioturbation took place as is evident from massive burrowing. In the tidal flat environment, after burrowing, desiccation and the forming of mudcracks took place due to subaerial exposure. Next, shallow burial of the McKee produced dewatering of mudstones interlaminated with sandstones as is evident from rare but distinguishable flame structures. After further burial, recrystallization of micritic mud and carbonate fossil fragments occurred. The final alteration of the McKee took place by precipitation of quartz overgrowths followed by authigenic clay growth.

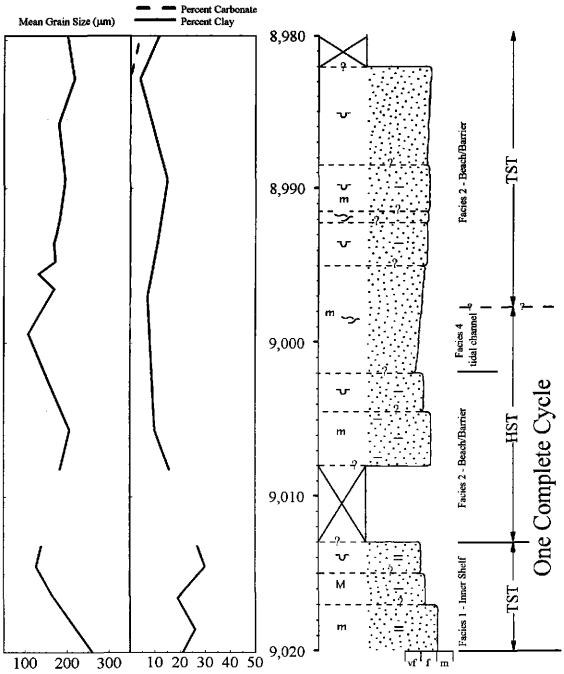

Fig. 23. Ideal stratigraphic sequence in the McKee Sand from the CONOCO Warren McKee #27 core showing a single cycle of transgressive systems tract (TST) innershelf facies (facies 1) overlain by highstand systems tract (HST) beach/barrier and tidal channel facies (facies 2 and 4 respectively).

CONCLUSIONS

The lower Paleozoic rocks deposited on the inner craton of North America are characterized by thick sections of carbonate rocks separated by thin units of sandstones and shales that were deposited during a relative highstand (Wilson, 1975) in a shallow epicontinental sea. One of these sandstones, the McKee Sand in the Tobosa Basin is a result of cyclic sea-level changes, during a relative highstand on the North American craton. Changes in quartz sand grain size and percentage of clay and carbonate composition accompanied by sharp breaks and repetition in facies delineate this cyclicity. Therefore, the McKee was deposited as a result of several smaller progradational highstands and transgressions as opposed to a single higher order highstand event.

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APPENDIX

The following pages include:

1. Legend of graphical core description symbols and abbreviations

2. Grain size analysis data, petrographic analysis data, graphical lithology logs, written core descriptions, and maximum entropy histograms for cores:

   ARCO State Y-4
   CONOCO Lockhart B12 #4E
   CONOCO Warren McKee #27
   ARCO University A-11-5
   ARCO University C-11-3
   ARCO University D-11-3
   ARCO University B-31-2
   ARCO University Pl-31-2

Legend

Lithology


Sandstone


Shale


Limestone

Sandy, 10 to 25% and 25 to 50%

Clayey, 10 to 25% and 25 to 50%

Limey, 10 to 25% and 25 to 50%

Coarse sand or gravel rock fragments

Sand lense


Sand stringer

Fossils

Contacts

Sharp, planar

Sharp, wavy


Gradational

Missing

Bedding

Lamination, planar

Cross-lamination

Lamination, wavy, parallel

Lamination, wavy, non-parallel

Mottled

Burrowed

Massive

Burrows

Mudcracks

Colors

B	Brown
Bk	Black
Bl	Blue
d	Dark
du	Dusky
G	Green
Gr	Gray
l	Light
m	Medium
mt	Moderate
O	Orange
o	Olive
p	Pale
R	Red
vdu	Very dusky
vl	Very light
vp	Very pale
Y	Yellow

GRAIN SIZE ANALYSIS
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.
SY-1	7697.8	179.52	139.89	108.13
SY-2	7692.7	146.06	116.28	84.63
SY-3	7689.1	174.91	128.65	99.98
SY-5	7687.5	131.73	98.71	90.81
SY-4	7682.1	165.66	108.96	109.56
SY-6	7677.0	192.19	149.35	110.08
SY-7	7676.2	189.99	154.86	103.76
SY-8	7666.0-7667.0	194.92	159.32	108.73
SY-9	7662.6	182.47	121.82	111.43
SY-10	7656.0-7657.0	151.70	127.84	72.52
SY-11	7651.0-7652.0	112.90	104.15	38.67
SY-12	7644.0-7645.0	229.00	215.07	128.12
SY-13	7640.8	186.32	118.52	126.50
SY-14	7636.0	154.13	102.22	122.32
SY-15	7621.4	117.91	84.81	88.98
SY-16	7612.2	175.70	142.08	94.81
SY-17	7601.5	127.99	101.59	71.87
SY-18	7596.1	136.52	103.54	90.40
SY-19	7589.9	94.14	91.26	18.90
SY-20	7585.5-7586.0	144.54	135.97	50.71
SY-21	7581.8	147.10	120.30	78.71
SY-22	7579.5-7580.0	213.04	223.79	94.25
SY-23	7577.0-7578.0	108.44	90.73	58.75
SY-24	7573.5	118.25	104.08	51.69

PETROGRAPHIC ANALYSIS
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Sample #	Depth (ft.)	Detrital Composition [a]						Authigenic Composition & Porosity [b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
SY-1	7697.8	72 (98)	00 (00)	01 (02)	00 (00)	00 (00)	00 (00)	04	00	20	03
SY-2	7692.7	70 (75)	01 (01)	23 (25)	00 (00)	00 (00)	00 (00)	00	02	01	03
SY-3	7689.1	75 (92)	00 (00)	07 (08)	00 (00)	00 (00)	00 (00)	03	01	01	14
SY-4	7682.1	61 (76)	00 (00)	19 (24)	00 (00)	00 (00)	00 (00)	00	00	01	20
SY-5	7687.5	83 (98)	00 (00)	02 (02)	00 (00)	00 (00)	00 (00)	06	03	00	07
SY-6	7677.0	46 (69)	00 (00)	17 (26)	03 (04)	00 (00)	00 (01)	00	00	23	06
SY-7	7676.2	52 (88)	00 (00)	05 (08)	02 (04)	00 (00)	01 (01)	00	00	39	01
SY-8	7666.0-7667.0	82 (97)	00 (00)	00 (00)	02 (03)	00 (00)	00 (00)	06	01	00	09

[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

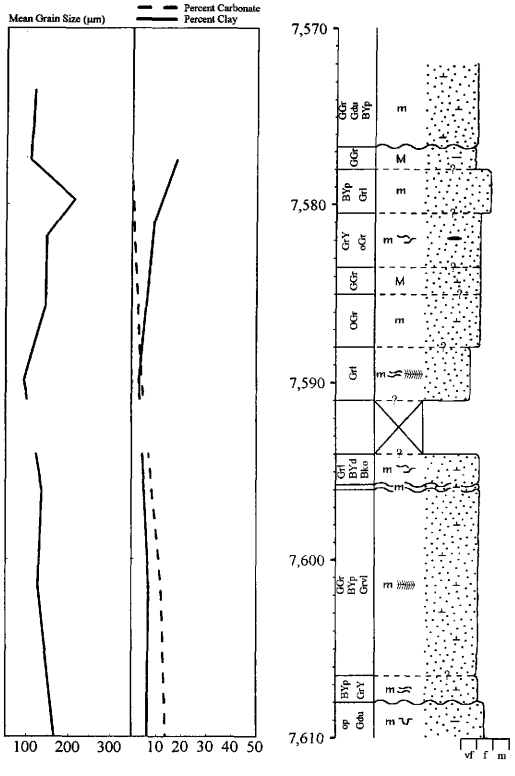
PETROGRAPHIC ANALYSIS (continued)
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Sample #	Depth (ft.)	Detrital Composition [a]						Authigenic Composition & Porosity [b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
SY-9	7662.6	69 (88)	00 (00)	08 (10)	01 (02)	00 (00)	00 (00)	00	03	14	06
SY-10	7656.0-7657.0	84 (98)	00 (00)	02 (02)	00 (00)	00 (00)	00 (00)	00	03	00	12
SY-12	7644.0-7645.0	55 (85)	00 (00)	09 (15)	00 (00)	00 (00)	00 (00)	00	00	16	20
SY-13	7640.8	68 (94)	00 (00)	04 (06)	01 (01)	00 (00)	00 (00)	01	00	20	06
SY-17	7601.5	69 (88)	00 (00)	05 (06)	04 (05)	00 (00)	00 (00)	00	02	12	08
SY-19	7589.9	78 (89)	00 (00)	03 (04)	06 (07)	00 (00)	00 (00)	05	00	04	03
SY-21	7581.8	46 (48)	38 (40)	08 (08)	03 (03)	00 (00)	00 (00)	00	01	01	02
SY-23	7577.0-7578.0	61 (70)	00 (00)	18 (20)	08 (09)	00 (00)	00 (00)	00	00	00	13

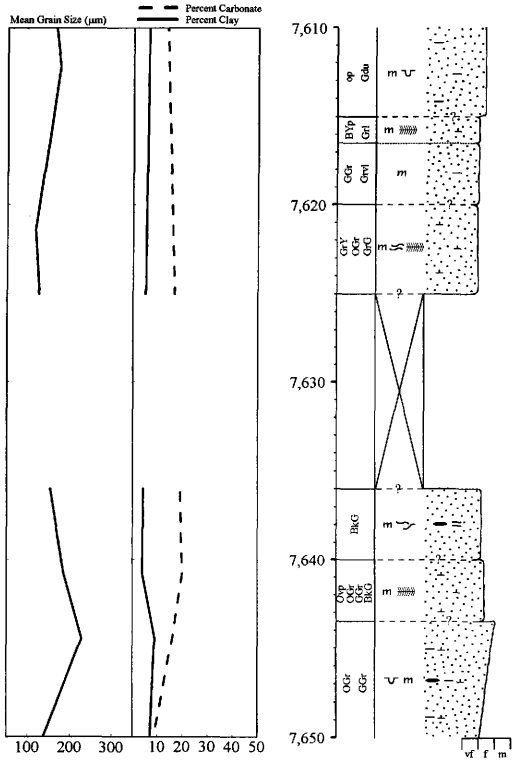
[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

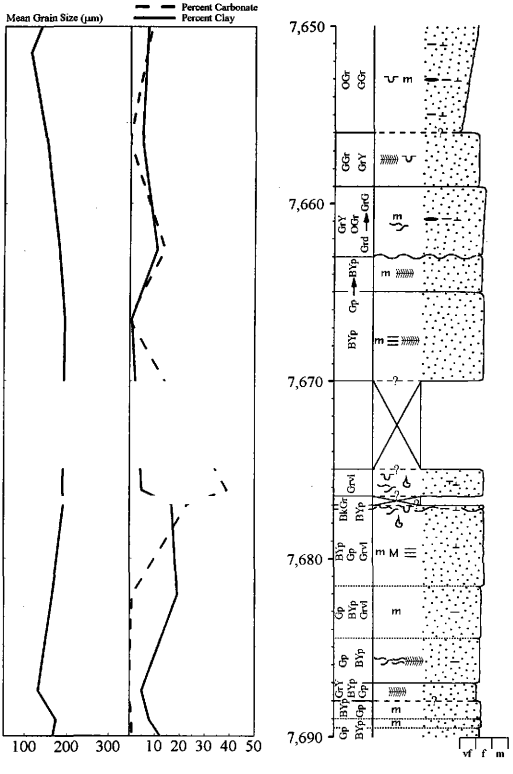
Detailed Graphic Lithology Log - ARCO State Y-4



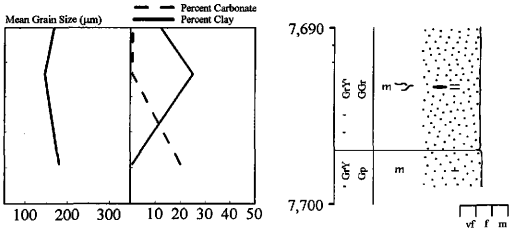
Detailed Graphic Lithology Log - ARCO State Y-4 (continued)



Detailed Graphic Lithology Log - ARCO State Y-4 (continued)



Detailed Graphic Lithology Log - ARCO State Y-4 (continued)



CORE DESCRIPTION
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7572.0 (2307.9)	4.7 (1.4)	SANDSTONE: fine grained with some medium grained, rounded, moderately well sorted, variable calcareousness, slightly friable; faintly mottled to well mottled grayish green (10G 4/2), dusky green (5G 3/2), and pale yellowish brown (10YR 6/2); some dark yellowish brown (10YR 4/2) in top 4/10'; burrows, skolithos in top 1'; sharp wavy lower contact.
7576.7 (2309.4)	1.3 (0.4)	SANDSTONE: medium grained with some fine grained, rounded, moderately well sorted, calcareous, muddy, very friable; grayish green (5G 3/2); massive; some spotty oxides; missing lower contact.
7578.0 (2309.8)	2.5 (0.8)	SANDSTONE: medium grained with some fine grained, rounded, well sorted, little mud, bottom ½ somewhat friable; mottled pale yellowish brown (10YR 6/2) and light gray (N7); sharp lower contact.
7580.5 (2310.5)	3.0 (1.0)	SANDSTONE: very fine to medium grained, abundant rounded greenish black (5G 2/1) rock fragments, angular to rounded, moderately well sorted, some mud; extremely mottled yellowish gray (5Y 8/1) and grayish olive (10Y 4/2); some wavy discontinuous sub-parallel laminae; distinct horizontal burrows; sharp lower contact.

CORE DESCRIPTION (continued)
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7583.5 (2311.5)	1.5 (0.5)	SANDSTONE: fine to medium grained with some very fine grained, moderately well sorted, sub-rounded, calcareous, friable; grayish green (10GY 5/2); massive; missing lower contact.
7585.0 (2311.9)	3.0 (1.0)	SANDSTONE: fine to medium grained with some very fine grained, sub-rounded to well rounded, moderately well sorted, calcareous, friable; grayish orange (10YR 7/4); faintly mottled; some oil streaks; missing lower contact.
7588.0 (2312.8)	3.0 (1.0)	SANDSTONE: fine grained with some very fine grained and medium grained, sub-rounded, moderately well sorted, calcareous; light gray (N6); mottled to wavy continuous to discontinuous, sub-parallel to parallel laminae, some cross-bedding; burrows; missing lower contact.
7591.0 (2313.7)	3.0 (1.0)	MISSING
7594.0 (2314.7)	1.7 (0.5)	SANDSTONE: very fine to medium grained, sub-angular to sub-rounded, poorly sorted, calcareous; mottled light gray (N7), dark yellowish brown (10YR 4/2), and olive black (5Y 2/1); some wavy discontinuous sub-parallel laminae; distinct lined-up horizontal burrows; sharp wavy lower contact.
7595.7 (2315.2)	0.3 (0.1)	SANDSTONE: mottled mixture of above and below units; burrows; sharp wavy lower contact.

CORE DESCRIPTION
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

(continued)

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7596.0 (2315.3)	10.5 (3.2)	SANDSTONE: fine to medium grained, sub-rounded to well rounded; mottled poorly sorted muddy grayish green (10G 4/2) sand and pale yellowish brown (10YR 6/2) sand interbedded with massive or cross-bedded fine grained, well sorted, very light gray (N8) calcareous sand; lighter green sands more friable; less distinctive interbedding towards top; 1/10' thick lense of greenish black (5GY 2/1) muddy sand at bottom with mottled to wavy discontinuous laminae; burrows from 7598.0' to 7599.0'; large fracture from 7597.5' to 7598.0'; 7596.5' to 7597.5' missing; sharp lower contact.
7606.5 (2318.5)	1.5 (0.5)	SANDSTONE: medium grained with some fine grained, rounded, well sorted, calcareous; faintly mottled pale yellowish brown (10YR 6/2) and yellowish gray (5Y 8/1); few wavy continuous parallel thick laminae; sharp wavy lower contact.
7608.0 (2318.9)	7.0 (2.1)	SANDSTONE: fine to medium grained, sub-rounded, moderately well sorted, occasional very light gray (N8) calcareous spotty areas; less muddy, more friable pale olive (10Y 6/2) through very muddy dusky green (5G 3/2); mottled to burrowed; abundant burrows, skolithos; sharp lower contact.

CORE DESCRIPTION (continued)
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7615.0 (2321.1)	1.5 (0.5)	SANDSTONE: fine to medium grained with abundant fine grained, sub-rounded, moderately well sorted, some spotty or poorly bedded calcareous light gray (N7) sand; faintly mottled to massive pale yellowish brown (10YR 6/2), some very faint cross-bedding; graded lower contact.
7616.5 (2321.5)	3.5 (1.1)	SANDSTONE: fine to medium, rounded, well sorted near bottom grading to poorly sorted near top, very muddy, friable near bottom; faintly mottled grayish green (10G 4/2) and very light gray (N8); burrows, skolithos; sharp lower contact.
7620.0 (2322.6)	5.0 (1.5)	SANDSTONE: medium grained, rounded, moderately well sorted, calcareous, variable amounts of very fine grained and mud, friable; mottled yellowish gray (5Y 8/1), grayish orange (10YR 7/4), and grayish green (10G 4/2); cross-bedding in yellowish gray (5Y 8/1) calcareous sand from 7621.7' to 7622.0'; one wavy continuous inclined (10 deg.) 1/10' thick bed of yellowish gray (5Y 8/1) calcareous sand at 7621.2'; missing lower contact.
7625.0 (2324.1)	11.0 (3.4)	MISSING

CORE DESCRIPTION
ARCO State Y-4 (continued)
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7636.0 (2327.5)	4.0 (1.2)	SANDSTONE: fine to coarse grained, rounded to well rounded, poorly sorted, rounded flattened coarse grained and gravel rock fragment clasts near top, calcareous, very muddy; greenish black (5GY 2/1) with greenish black (5GY 2/1) and very light gray (N8) clasts; mottled to wavy discontinuous sub-parallel laminae; burrows; orange carbonates; sharp lower contact.
7640.0 (2328.7)	3.5 (1.1)	SANDSTONE: medium grained with some fine grained, rounded to well rounded, well sorted; mottled and poorly interbedded very pale orange (10YR 8/2), grayish orange (10YR 7/4), muddy grayish green (10G 4/2), and muddy greenish black (5GY 2/1); cross-bedding at 7641.4' to 7641.6'; burrows, skolithos; sharp lower contact.
7643.5 (2329.7)	12.5 (3.8)	SANDSTONE: fine grained grading to medium grained, sub-rounded grading to rounded, moderately well sorted grading to well sorted, dispersed black gravel rock fragments, bottom 6' calcareous, slightly to extremely friable, darkest green least friable, muddy; grayish orange (10YR 7/4) to grayish green (10G 4/2); burrowed to mottled; burrows, some filled with grayish green (10G 4/2) mud; sharp lower contact.

CORE DESCRIPTION (continued)
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7656.0 (2333.5)	3.0 (1.0)	SANDSTONE: medium grained with some fine grained thin beds, sub-rounded, moderately well sorted; cross-bedded grayish green (5G 5/2), yellowish gray (5Y 8/1), and yellowish gray (5Y 7/1); burrows filled with fine grained sand and mud; sharp planar lower contact.
7659.0 (2334.5)	4.0 (1.2)	SANDSTONE: very fine to fine grained grading to fine to medium grained, sub-rounded to rounded, moderately well sorted, dispersed rounded gravel rock fragments at 7661.6'; calcareous yellowish gray (5Y 8/1) sand and grayish orange (10YR 7/2) sand with dark gray (N3) mud near bottom grading to grayish green (5G 5/2) mud; wavy continuous sub-parallel laminae grading to mottled; mottled grayish green (5G 5/2) and grayish orange (10YR 7/2) 2/10' thick layer 1/20' from bottom; skolithos burrows from 7660.0' to 7660.5'; carbonate filled fractures in top 1'; sharp wavy lower contact.
7663.0 (2335.7)	2.0 (0.6)	SANDSTONE: medium grained with some very fine to fine grained, sub-rounded grading to rounded, moderately well sorted grading to well sorted, friable; bottom ½ pale green (10G 6/2), top ½ pale yellowish brown (10YR 6/2); very faintly mottled; faint cross-bedding from 7663.5' to 7664.0'; sharp planar lower contact.

CORE DESCRIPTION (continued)
ARCO State Y-4
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7665.0 (2336.3)	5.0 (1.5)	SANDSTONE: fine to medium grained, sub-rounded, moderately well sorted, calcareous; pale yellowish brown (10YR 6/2); faintly mottled to continuous to discontinuous parallel inclined (15 deg.) laminae; some faint cross-bedding; carbonate filled fractures from 7668.0' to 7669.0'; missing lower contact.
7670.0 (2337.8)	5.5 (1.7)	MISSING
7675.5 (2339.5)	1.0 (0.3)	SANDSTONE: fine grained grading to medium grained with some very fine grained, sub-rounded to rounded, well sorted, calcareous; massive very light gray (N8); some wavy discontinuous sub-parallel mud laminae near bottom; large escape burrow from top to 1/2' from top filled with dusky yellowish green (10G 3/2) muddy sand and pale yellowish brown (10YR 6/2) sand; very fossiliferous, shelly; missing lower contact.
7676.5 (2339.8)	0.5 (0.2)	MISSING
7677.0 (2339.9)	0.2 (0.1)	SANDSTONE: medium grained with some very fine and fine grained, sub-rounded to rounded, moderately well sorted, calcareous; grayish black (N2) and best fit pale yellowish brown (10YR 6/2) sand interlaminated and broken by burrows; wavy discontinuous sub-parallel laminae; burrows, some into lower unit; fossils, shell fragments; sharp wavy lower contact.

CORE DESCRIPTION
ARCO State Y-4 (continued)
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7677.2 (2340.0)	4.4 (1.3)	SANDSTONE: medium grained with some very fine grained, rounded, well sorted, calcareous, somewhat friable; homogenous massive pale green (5G 7/2) sand from 7678.5' to 7680.0', otherwise mottled of pale yellowish brown (10YR 6/2), pale green (5G 7/2), and very light gray (N8); one faint planar inclined (15 deg.) at 7681.1'; carbonate filled fractures from 7677.6' to 7678.0'; burrows from above unit in top 2/10'; gradational lower contact.
7681.6 (2341.4)	2.9 (0.9)	SANDSTONE: medium grained with some very fine grained, rounded, well sorted, calcareous, friable; somewhat faintly mottled pale green (5G 7/2) and pale yellowish brown (10YR 6/2); somewhat faintly mottled pale green (5G 7/2) and very light gray (N8) from 7682.5' to 7683.0'; more very fine grained in pale green (5G 7/2) sand; gradational lower contact.
7684.5 (2342.2)	2.5 (0.8)	SANDSTONE: fine grained with some medium grained, rounded, moderately well sorted, slightly calcareous, muddy, friable; wavy continuous sub-parallel to parallel pale green (5G 7/2) mixed with pale yellowish brown (10YR 6/2) laminae; some very faint cross-bedding from 7685.0' to 7685.5'; sharp planar lower contact.

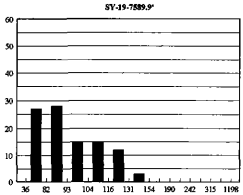
CORE DESCRIPTION
ARCO State Y-4 (continued)
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

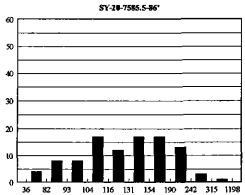
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7687.0 (2343.0)	1.0 (0.3)	SANDSTONE: fine to medium grained, rounded, well sorted, graded on 1/20' to 1/10' scale; yellowish gray (5Y 8/2) and pale yellowish brown (10YR 6/2) cross-bedding with some pale green (10G 6/2); top 1/10' planar continuous bedding; sharp lower contact.
7688.0 (2343.3)	1.0 (0.3)	SANDSTONE: medium grained with some fine grained, rounded, well sorted; mottled mainly pale yellowish brown (10YR 6/2) with a little muddy pale green (10G 6/2); gradational lower contact.
7689.0 (2343.6)	0.5 (0.2)	SANDSTONE: medium grained with some fine grained, rounded, well sorted, slightly calcareous; mottled pale green (10G 6/2) and pale yellowish brown (10YR 6/2); gradational lower contact.
7689.5 (2343.8)	7.5 (2.3)	SANDSTONE: medium grained with some very fine to fine grained, rounded with some sub-rounded, moderately well sorted, dispersed coarse to very coarse grained dark gray (N3) rock fragments decreasing upward from 7691.0', variable calcareousness, variable muddiness, somewhat friable; varying in color from calcareous yellowish gray (5Y 8/1) to grayish green (10G 4/2); mottled with some wavy discontinuous sub-parallel very thin laminae; heavily burrowed, zoophycus at 7692.4'; burrowed 1/10' thick mudstone bed 3/10' from bottom; sharp planar lower contact.

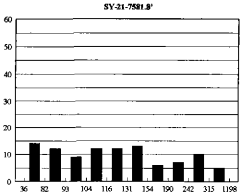
CORE DESCRIPTION
ARCO State Y-4 (continued)
Justis (McKee) Field
Lea County, New Mexico
T25S, R37E, Section 25
Core: 7572.0-7699.0 feet

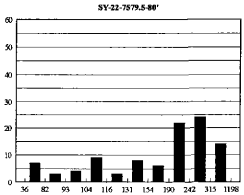
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7697.0 (2346.0)	2.0 (0.6)	SANDSTONE: medium grained, sub-rounded, well sorted, very coarse rock fragments decreasing upward, calcareous, some pale green (10G 6/2) clay; mottled yellowish gray (5Y 8/1) and pale green (10G 6/2); pyritized fossil near base.
7699.0 (2346.7)		END CORE

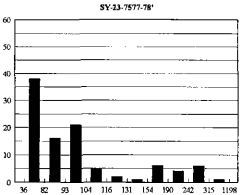
Maximum Entropy Histograms - ARCO State Y-4 (continued)

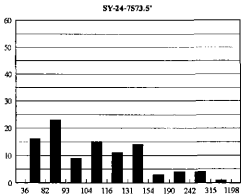




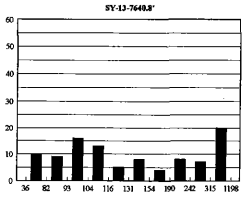


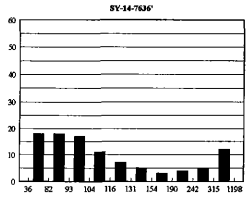


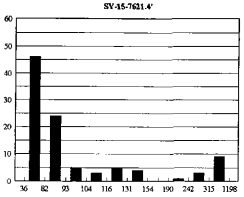


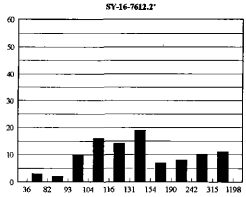


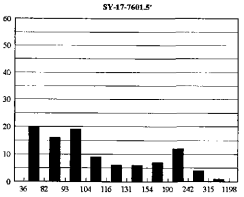
Maximum Entropy Histograms - ARCO State Y-4 (continued)

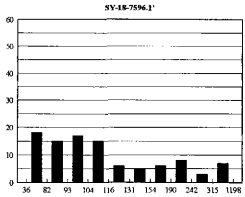




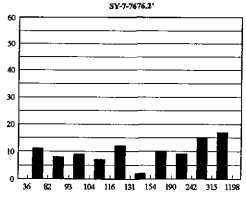


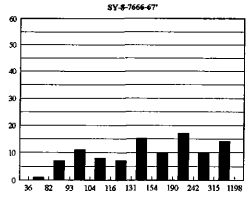


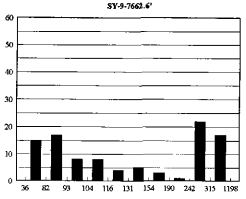


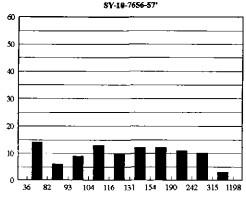


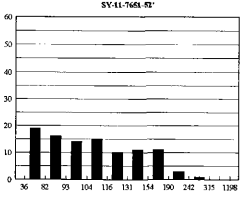
Maximum Entropy Histograms - ARCO State Y-4 (continued)

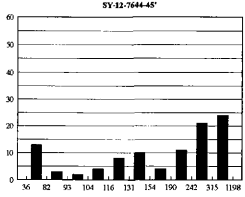




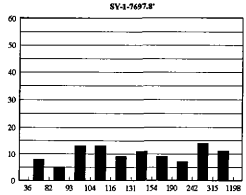


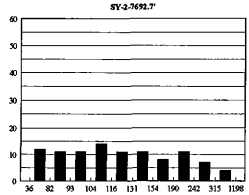


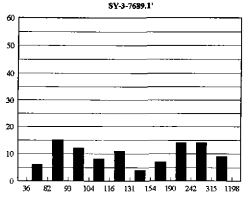


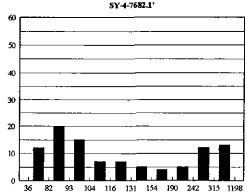


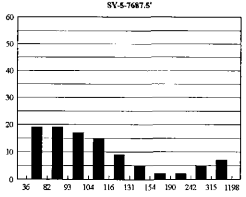
Maximum Entropy Histograms - ARCO State Y-4

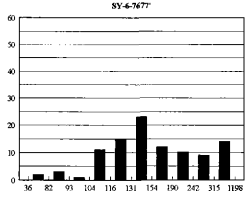












GRAIN SIZE ANALYSIS
CONOCO Lockhart B12 #4E
Brunson Field
Lea County, New Mexico
T21S, R37E, Section 12
Core: 7672.0-7709.5 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.
L-1	7674.7	114.71	99.80	45.14
L-2	7675.7	101.70	93.15	30.15
L-3	7684.0	139.11	114.73	60.79
L-4	~7692.3	97.49	93.61	28.06
L-5	~7693.8	138.31	119.64	58.62
L-6	7705.1	103.87	97.18	33.36
L-7	~7707.0	132.35	121.61	48.02
L-8	~7708.8	150.34	141.25	56.67

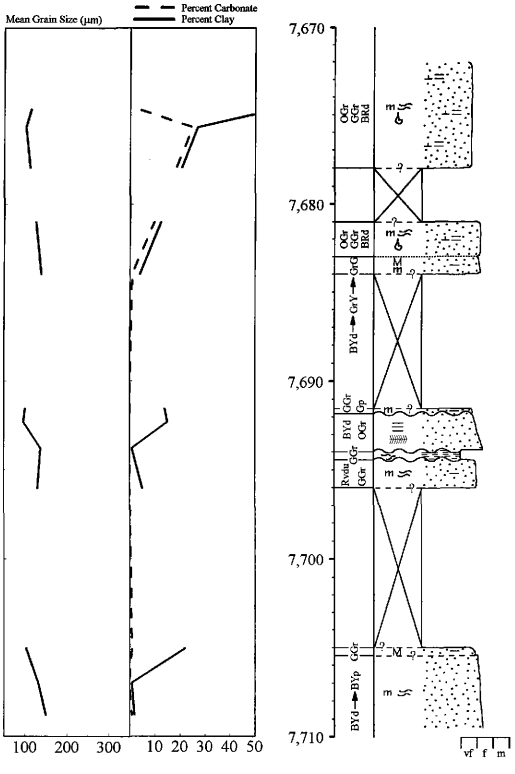
PETROGRAPHIC ANALYSIS
CONOCO Lockhart B12 #4E
Brunson Field
Lea County, New Mexico
T21S, R37E, Section 12
Core: 7672.0-7709.5 feet

Sample #	Depth (ft.)	Detrital Composition [a]						Authigenic Composition & Porosity [b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
L-1	7674.7	34 (36)	00 (00)	58 (61)	00 (00)	00 (00)	02 (03)	00	00	04	00
L-2	7675.7	49 (65)	00 (00)	27 (35)	00 (00)	00 (00)	00 (00)	00	00	25	00
L-3	7684.0	79 (97)	00 (00)	02 (03)	00 (00)	00 (00)	00 (00)	02	02	01	13
L-4	~7692.3	67 (91)	00 (00)	06 (08)	00 (00)	00 (00)	01 (01)	03	09	00	15
L-5	~7693.8	84 (100)	00 (00)	00 (00)	00 (00)	00 (00)	00 (00)	03	01	00	12
L-6	7705.1	67 (77)	00 (00)	20 (23)	00 (00)	00 (00)	00 (00)	01	02	01	09
L-7	~7707.0	74 (96)	03 (04)	00 (00)	00 (00)	00 (00)	00 (00)	04	01	00	18
L-8	~7708.8	79 (97)	02 (03)	00 (00)	00 (00)	00 (00)	00 (00)	02	02	01	13

[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

Detailed Graphic Lithology Log - CONOCO Lockhart B12 #4E



CORE DESCRIPTION
CONOCO Lockhart B12 #4E
Brunson Field
Lea County, New Mexico
T21S, R37E, Section 12
Core: 7620.0-7709.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7672.0 (2338.4)	11.0 (3.4)	SANDSTONE: very fine to medium grained, well rounded to rounded, poorly sorted, very muddy, calcareous; mottled dark reddish brown (10R 3/4), grayish green (5G 5/2), and grayish orange (10YR 7/4); some wavy irregular laminae (<20 deg.); some flame structures; fossiliferousness varying in layers, brachiopods; burrows into underlying unit; 7678' to 7681' missing; gradational lower contact.
7683.0 (2341.8)	1.0 (0.3)	SANDSTONE: very fine to coarse grained, graded except top 1/10', sub-angular to sub-rounded, poorly sorted, little mud overall except top 1/10' which is muddy, little calcite, slightly friable; top 1/10' is massive greenish gray (5G 6/1); 1/10' to 4/10' from top is massive yellowish gray (5Y 7/2); 4/10' and below wavy continuous parallel thick laminae to mottled yellowish gray (5Y 7/2), dark yellowish brown (10YR 4/2), and greenish gray (5G 6/1); dark yellowish brown (10YR 4/2) is oil staining; missing lower contact.
7684.0 (2342.1)	7.5 (2.3)	MISSING
7691.5 (2344.4)	0.3 (0.1)	SANDSTONE: very fine to fine grained, sub-rounded to well-rounded, very poorly sorted, very muddy, slightly friable; mottled grayish green (5G 5/2) and pale green (10G 6/2); burrows into underlying unit; sharp wavy lower contact.

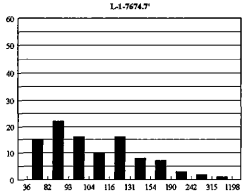
CORE DESCRIPTION
CONOCO Lockhart B12 #4E (continued)
Brunson Field
Lea County, New Mexico
T21S, R37E, Section 12
Core: 7620.0-7709.5 feet

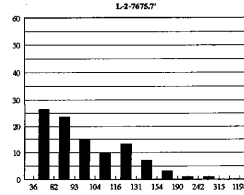
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7691.8 (2344.5)	2.1 (0.6)	SANDSTONE: fine to medium grained, sub-rounded, well sorted; planar continuous parallel inclined (20 deg.) dark yellowish brown (10YR 4/2) and grayish orange (10YR 7/2) thin bedding, little green mud; bottom 8/10' cross-laminated grayish orange (10YR 7/2) and grayish black (N2) and thinly bedded; dark yellowish brown (10YR 4/2) is oil staining; horizontal and 30 deg. fractures filled with clean sand; missing lower contact.
7693.9 (2345.1)	0.5 (0.2)	MUDSTONE: sandy, very fine to coarse grained sand; wavy discontinuous non-parallel inclined (<20 deg.) grayish green (5G 5/2) and grayish green (10G 5/2) laminae; sharp wavy lower contact.
7694.4 (2345.3)	1.6 (0.5)	SANDSTONE: very fine grained, sub-angular, moderately well sorted, muddy; mottled very dusky red (10R 2/2) with grayish green (5G 5/2) and some light olive green (5Y 6/1); some wavy continuous parallel inclined (~20 deg.) laminae near bottom; missing lower contact.
7696.0 (2345.7)	9.0 (2.7)	MISSING
7705.0 (2348.5)	0.4 (0.1)	SANDSTONE: very fine to medium grained, sub-angular to sub-rounded, poorly sorted, very friable, slightly calcareous, very little clay; grayish green (10G 5/2); massive; missing lower contact.

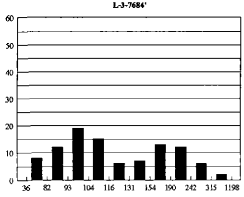
CORE DESCRIPTION (continued)
CONOCO Lockhart B12 #4E
Brunson Field
Lea County, New Mexico
T21S, R37E, Section 12
Core: 7620.0-7709.5 feet

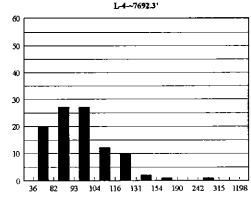
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
7705.4 (2348.6)	4.1 (1.2)	SANDSTONE: fine to medium grained, rounded to well rounded, well sorted, little clay, variable friability; mottled pale yellowish brown (10YR 6/2) and dark yellowish brown (10YR 4/2) with little grayish green (10GY 5/2) clay; some wavy continuous inclined (~20 deg.) bedding; more dark yellowish brown (10YR 4/2) oil staining towards bottom; slight hydrocarbon odor.
7709.5 (2349.9)		END CORE

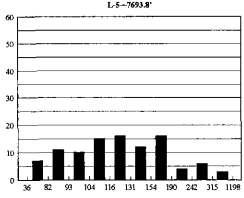
Maximum Entropy Histograms - CONOCO Lockhart B12 #4E

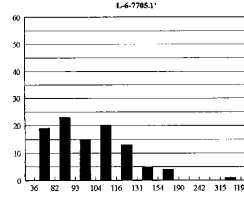




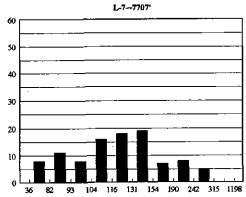


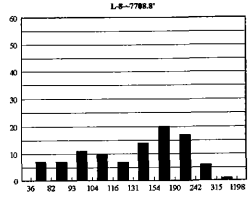






Maximum Entropy Histograms - CONOCO Lockhart B12 #4E (continued)





GRAIN SIZE ANALYSIS
CONOCO Warren McKee #27
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.
WMK-1	8940.4	304.37	264.37	150.62
WMK-2	8941.9	248.10	222.12	148.66
WMK-3	~8942.0	226.83	197.20	121.99
WMK-4	8944.0	156.63	127.86	72.54
WMK-5	8945.5	114.04	109.36	35.83
WMK-6	8948.5	101.10	99.36	21.07
WMK-8	8951.6	120.84	96.27	65.43
WMK-9	8951.9	168.58	123.27	115.67
WMK-10	8952.4	156.17	127.66	87.30
WMK-11	8952.0-8953.0	156.69	128.46	76.61
WMK-12	8955.3	137.10	123.30	44.48
WMK-13	8958.0	183.64	161.04	86.03
WMK-14	8959.3	199.79	179.21	104.93
WMK-15	8960.4	133.14	134.13	39.87
WMK-17	8962.7	146.80	131.46	58.79
WMK-19	8966.3	175.29	158.08	87.44
WMK-20	8971.7	150.82	128.76	64.06
WMK-21	8982.8	216.68	193.30	103.32
WMK-22	8985.8	179.87	156.28	111.60
WMK-23	8989.4	194.61	174.81	80.10
WMK-24	8992.0	181.27	134.72	111.23
WMK-25	~8993.0	173.56	139.59	92.03
WMK-26	8993.0-8994.0	167.94	128.86	111.18
WMK-27	8994.7	170.71	131.46	90.18
WMK-28	8995.0-8996.0	131.80	101.60	92.07
WMK-29	8995.0-8998.0	168.74	128.47	92.68
WMK-30	8999.4	107.73	99.21	39.92
WMK-31	9002.0-9003.0	156.04	130.78	85.95
WMK-32	9005.6	206.20	163.98	124.79

GRAIN SIZE ANALYSIS
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.
WMK-33	9014.5	126.61	101.84	68.90
WMK-34	9016.0-9017.0	168.97	128.03	106.93
WMK-35	9020.0-9021.0	274.10	265.94	110.03
WMK-36	9031.0-9034.0	150.95	121.41	81.46
WMK-37	9034.0-9043.0	142.59	111.78	80.75
WMK-38	9040.0-9043.0	144.95	120.40	63.19
WMK-39	9048.0-9049.0	111.94	102.85	38.47
WMK-40	9053.0-9054.0	121.46	104.80	59.78
WMK-41	9055.9	132.30	96.78	78.86
WMK-42	9058.2	171.98	131.68	97.94
WMK-43	9061.0-9062.0	142.68	117.49	70.38
WMK-44	9062.0-9063.0	179.06	156.84	83.16
WMK-45	9065.0-9066.0	153.34	132.63	78.28
WMK-46	9066.0-9067.0	180.89	170.37	73.11
WMK-47	9073.0-9074.0	158.30	116.86	104.81

PETROGRAPHIC ANALYSIS
CONOCO Warren McKee #27
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Sample #	Depth (ft.)	Detrital Composition [a]						Authigenic Composition & Porosity [b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
WMK-5	8945.5	74 (98)	00 (00)	01 (02)	00 (00)	00 (00)	00 (00)	04	13	02	07
WMK-11	8955.3	71 (89)	00 (00)	06 (07)	02 (03)	00 (00)	00 (00)	01	04	00	14
WMK-16	8963.3	79 (94)	00 (00)	02 (03)	02 (03)	00 (00)	00 (00)	02	01	06	09
WMK-18	8966.3	55 (65)	00 (00)	26 (31)	01 (01)	00 (00)	03 (03)	00	03	09	03
WMK-20	8971.7	64 (66)	00 (00)	31 (32)	01 (01)	00 (00)	01 (01)	00	01	02	01
WMK-21	8976.5	68 (86)	00 (00)	10 (13)	01 (01)	00 (00)	00 (00)	00	11	09	02
WMK-22	8982.8	74 (96)	00 (00)	01 (02)	01 (02)	00 (00)	00 (00)	03	03	00	18
WMK-24	8989.4	72 (88)	00 (00)	09 (11)	00 (00)	00 (00)	01 (02)	00	06	00	12

[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

PETROGRAPHIC ANALYSIS
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
WMK-26	8993.0-8994.0	68 (90)	00 (00)	07 (09)	01 (01)	00 (00)	00 (00)	00	04	00	21
WMK-30	~8997.0	77 (96)	00 (00)	02 (02)	02 (02)	00 (00)	00 (00)	01	05	00	14
WMK-32	9005.6	70 (90)	00 (00)	06 (07)	03 (04)	00 (00)	00 (00)	00	04	00	18
WMK-33	9014.5	59 (62)	00 (00)	28 (30)	06 (06)	00 (00)	02 (02)	00	02	00	03
WMK-34	9016.0-9017.0	60 (75)	00 (00)	18 (23)	02 (02)	00 (00)	00 (00)	00	01	00	20
WMK-35	9018.0-9019.0	54 (68)	00 (00)	26 (32)	00 (00)	00 (00)	00 (00)	00	00	00	20
WMK-36	9022.0-9023.0	75 (84)	01 (02)	12 (13)	01 (01)	00 (00)	00 (00)	00	01	00	10
WMK-37	9032.0	62 (63)	00 (00)	37 (38)	00 (00)	00 (00)	00 (00)	00	00	00	01

[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

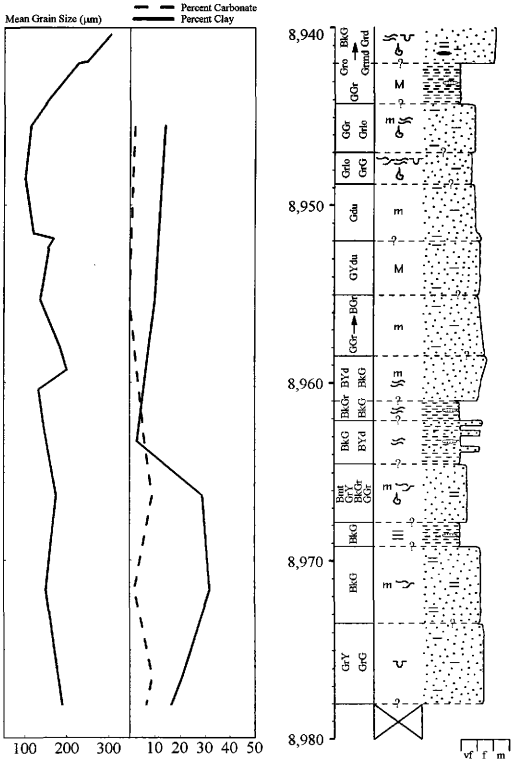
PETROGRAPHIC ANALYSIS
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
WMK-38	9037 ?	82 (95)	00 (00)	00 (00)	02 (03)	00 (00)	02 (02)	06	00	00	08
WMK-39	9040.0-9043.0	60 (80)	00 (00)	15 (20)	00 (00)	00 (00)	00 (00)	00	01	00	25
WMK-40	9048.0-9049.0	73 (97)	00 (00)	02 (03)	00 (00)	00 (00)	00 (00)	00	04	01	19
WMK-43	9058.2	84 (98)	00 (00)	01 (01)	00 (00)	00 (00)	01 (01)	03	01	00	11
WMK-46	9065.0-9066.0	79 (96)	00 (00)	03 (04)	00 (00)	00 (00)	00 (00)	01	01	01	15
WMK-50	9073.0-9074.0	67 (69)	03 (03)	21 (21)	06 (06)	00 (00)	01 (01)	01	02	00	00

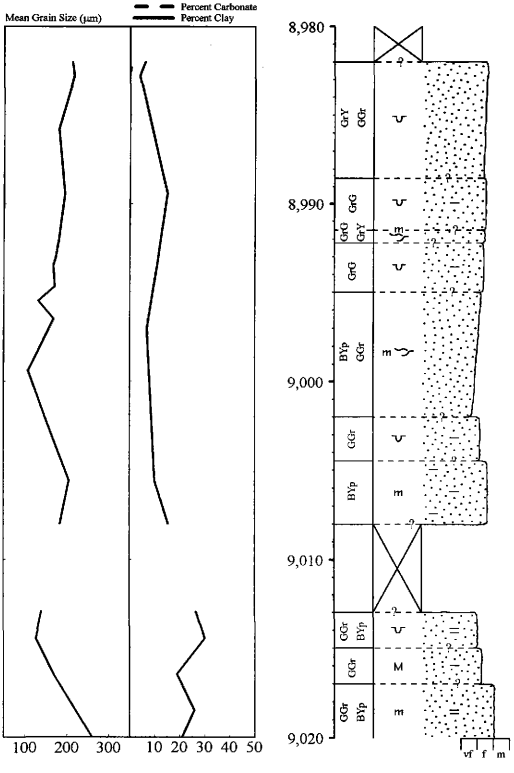
[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

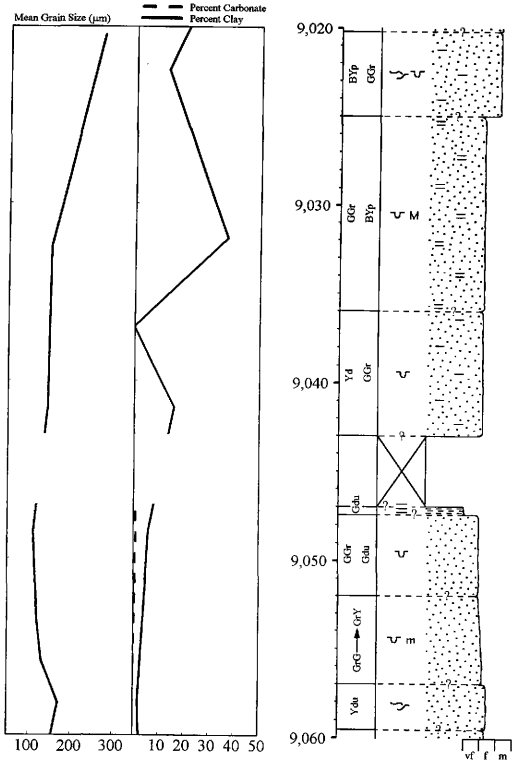
Detailed Graphic Lithology Log - CONOCO Warren McKee #27



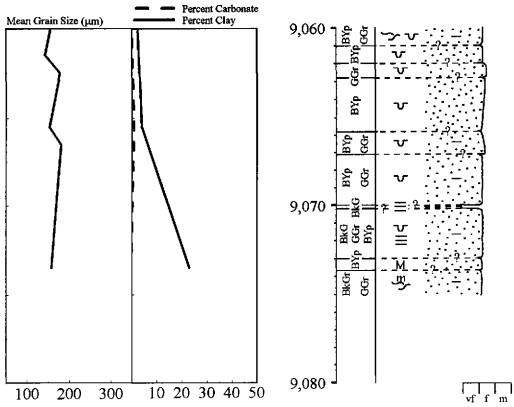
Detailed Graphic Lithology Log - CONOCO Warren McKee #27 (continued)



Detailed Graphic Lithology Log - CONOCO Warren McKee #27 (continued)



Detailed Graphic Lithology Log - CONOCO Warren McKee #27 (continued)



CORE DESCRIPTION
CONOCO Warren McKee #27
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8940.0 (2724.9)	2.0 (0.6)	SANDSTONE: very fine grained, sub-angular, poorly sorted, grading to mudstone, calcareous, gravel clasts in bottom, friable; olive gray (5Y 4/1) and medium dark gray (N4) sand grading to greenish black (5GY 2/1) and dark gray (N3) mudstone; wavy discontinuous laminae; burrows; fossils, brachiopods; sharp lower contact.
8942.0 (2725.5)	2.2 (0.7)	MUDSTONE: grayish green (10G 4/2); lenses of (½" by 2") coarse sub-angular sand sub-parallel to bedding with variable orientation; massive; missing lower contact.
8944.2 (2726.2)	2.8 (0.9)	SANDSTONE: fine grained, sub-rounded, well sorted, friable; mottled grayish green (10GY 5/2) and light olive gray (5Y 5/2); few muddy wavy laminae; burrows, skolithos; fossils; some burrows and fossils replaced with oxides; missing lower contact.
8947.0 (2727.0)	1.8 (0.5)	SANDSTONE: very fine to fine grained with some medium, sub-angular, well sorted, muddy; light olive gray (5Y 5/2) to muddy greenish gray (5G 4/1); wavy continuous to discontinuous sub-parallel to parallel laminae; greenish gray (5G 4/1) mudstone bed from 8949.1' to 8949.2'; some spotty hematite; burrows; some fossils and burrows replaced by chalcopyrite; missing lower contact.

CORE DESCRIPTION
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8948.8 (2727.6)	3.2 (1.0)	SANDSTONE: medium grained, sub-angular, moderately well sorted, muddy; mottled dusky green (5G 3/2); many burrows, sclarituba, skolithos; missing lower contact.
8952.0 (2728.6)	3.0 (0.9)	SANDSTONE: medium grain with coarse silt, sub-angular to rounded, moderately well sorted, extremely friable; dusky yellow green (5GY 5/2); massive; missing lower contact.
8955.0 (2729.5)	3.4 (1.0)	SANDSTONE: medium to coarse grained, slight grading, rounded to well rounded, poorly sorted, friable; greenish gray (5GY 6/1) grading to grayish brown (5YR 3/2); mottled; burrows, skolithos; missing lower contact.
8958.4 (2730.5)	2.6 (0.8)	SANDSTONE: medium to coarse grained grading to very fine to fine grained, well rounded grading to sub-rounded, moderately well sorted grading to very well sorted, friable; dark yellowish brown (10YR 2/4) and greenish black (5GY 2/1); wavy continuous parallel laminae grading to mottled; in top 1.2' burrows, skolithos; missing lower contact.
8961.0 (2731.3)	1.1 (0.3)	MUDSTONE: grayish black (N2) to greenish black (5G 2/1); wavy continuous parallel laminae; some sub-rounded medium to coarse grained sand stringers; missing lower contact.

CORE DESCRIPTION (continued)
CONOCO Warren McKee #27
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8962.1 (2731.6)	2.4 (0.7)	MUDSTONE: greenish black (5G 2/1); sand stringers; wavy continuous parallel laminae; interbedded with and coarsening upward to fine to medium grained angular to sub-angular well sorted dark yellowish brown (10YR 4/2) sandstone; ripple drift laminae in sand; sparse burrows; missing lower contact.
8964.5 (2732.4)	3.3 (1.0)	SANDSTONE: very fine grained with some coarse silt, sub-angular to sub-rounded, very well sorted, slightly friable; mottled moderate brown (5YR 3/4), yellowish gray (5Y 7/2), and grayish black (N2) to grayish green (5G 5/2); some wavy sub-parallel laminae; fossils, brachiopods; burrows, skolithos; missing lower contact.
8967.8 (2733.4)	1.4 (0.4)	SHALE: greenish black (5G 2/1); sub-rounded fine to medium sand stringer; missing lower contact.
8969.2 (2733.8)	4.3 (1.3)	SANDSTONE: fine to medium grained with some coarse grained, rounded, moderately well sorted to well sorted, very muddy; greenish black (5GY 2/1); mottled, some wavy discontinuous sub-parallel laminae; burrows filled with pale yellowish brown (10YR 6/2) or spotty grayish red (10R 4/2) sand, skolithos; missing lower contact.
8973.5 (2735.1)	4.5 (1.4)	SANDSTONE: medium, rounded, well sorted to very well sorted, some mud, friable; yellowish gray (5Y 7/2) to greenish gray (10G 4/2); burrowed; burrows, skolithos; spotty hematite, some bands where more frequent; missing lower contact.

CORE DESCRIPTION
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8978.0 (2736.5)	4.0 (1.2)	MISSING
8982.0 (2737.7)	6.5 (2.0)	SANDSTONE: medium grained, rounded to well rounded, very well sorted, becoming less muddy towards top, fairly friable; sandier yellowish gray (5Y 7/2) to muddier grayish green (5G 5/2); bioturbated; burrows, ophiomorpha in top 2 ½ ', skolithos below; spotty hematite more common in muddier areas; missing lower contact.
8988.5 (2739.7)	3.0 (0.9)	SANDSTONE: medium grained with some fine and coarse grained, sub-rounded, poorly sorted, muddier towards top; greenish gray (5GY 6/1); burrowed; burrows with pale yellowish brown (10YR 6/2) burrow fill, skolithos; spotty hematite more common in muddier areas; missing lower contact.
8991.5 (2740.6)	0.7 (0.2)	SANDSTONE: medium to coarse grained with some fine grained, sub-rounded, moderately well sorted, friable; mottled greenish gray (5GY 6/1) to yellowish gray (5Y 7/2); some wavy discontinuous sub-parallel very thin laminae near bottom; burrows, yellowish gray (5Y 7/2) burrow fill, skolithos; scattered spotty hematite and some pyrite; missing lower contact.

CORE DESCRIPTION
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8992.2 (2740.8)	2.8 (0.9)	SANDSTONE: medium to coarse grained, sub-angular to sub-rounded, poorly sorted, very friable; grayish green (10GY 5/2); burrowed; burrows, yellowish gray (5Y 7/2) burrow fill, skolithos; missing lower contact.
8995.0 (2741.7)	7.0 (2.1)	SANDSTONE: fine to medium grained, well rounded, very poorly sorted, muddy around center, friable near top and bottom; mottled pale yellowish brown (10YR 6/2) and grayish green (10GY 5/2); few wavy continuous to discontinuous sub-parallel laminae near center; heavily burrowed, ophiomorpha, skolithos; missing lower contact.
9002.0 (2743.8)	2.5 (0.8)	SANDSTONE: fine to medium grained, well rounded, moderately well sorted, clayey, very friable near top; grayish green (10G 4/2); heavily burrowed; burrows, filled with pale yellowish brown (10YR 6/2) sand, skolithos, ophiomorpha; missing lower contact.
9004.5 (2744.6)	3.5 (1.1)	SANDSTONE: medium grained, well rounded, extremely well sorted, friable; very faintly mottled pale yellowish brown (10YR 6/2); missing lower contact.
9008.0 (2745.6)	5.0 (1.5)	MISSING

CORE DESCRIPTION (continued)
CONOCO Warren McKee #27
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9013.0 (2747.2)	2.0 (0.6)	SANDSTONE: fine to medium grained, well rounded, very well sorted, friable; muddy grayish green (5G 5/2) and pale yellowish brown (10YR 6/2); burrowed; heavily burrowed, thalassinoides; missing lower contact.
9015.0 (2747.8)	2.0 (0.6)	SANDSTONE: medium grained with some coarse silt, well rounded, poorly sorted, muddy, very friable; grayish green (5G 5/2); massive; missing lower contact.
9017.0 (2748.4)	3.2 (1.0)	SANDSTONE: medium grained, well rounded, well sorted, friable; mottled muddy grayish green (5G 5/2) and pale yellowish brown (10YR 6/2); heavily burrowed, filled with pale yellowish brown sand (10YR 6/2) thalassinoides; missing lower contact.
9020.2 (2749.4)	4.8 (1.5)	SANDSTONE: very fine to fine grained, well rounded, moderately well sorted, very friable; pale yellowish brown (10YR 6/2) with wavy discontinuous sub-parallel grayish green (5G 5/2) laminae; two sets of flasers at 9021.1'; heavily burrowed; missing lower contact.
9025.0 (2750.8)	11.0 (3.4)	SANDSTONE: fine to medium grained with some coarse silt, well rounded, well sorted, very friable; grayish green (5G 5/2) with some pale yellowish brown (10YR 6/2); burrowed to massive; burrows in lower ½ of unit, skolithos; missing lower contact.

CORE DESCRIPTION
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9036.0 (2754.2)	7.0 (2.1)	SANDSTONE: fine to medium grained, well rounded, very friable; very well sorted dusky yellow (5Y 6/4) sand with some moderately well sorted muddy grayish green (10G 5/2) sand; burrowed; heavily burrowed, ophiomorpha; some spotty hematite in muddy grayish green (10G 5/2) sand; missing lower contact.
9043.0 (2756.3)	4.0 (1.2)	MISSING
9047.0 (2757.5)	0.4 (0.1)	SHALE: dusky green (5G 3/2); some very fine sub-rounded to well rounded sand; missing lower contact.
9047.4 (2757.6)	4.6 (1.4)	SANDSTONE: fine grained with some coarse silt, well rounded, moderately well sorted, very friable; grayish green (10G 5/2) sand and dusky green (5G 3/2) mud; burrowed; interbedded near bottom; burrows; sand lenses in mud units; some spotty hematite; missing lower contact.
9052.0 (2759.0)	5.0 (1.5)	SANDSTONE: medium grained, well rounded, well sorted, very friable; greenish gray (5G 5/2) grading to yellowish gray (5Y 7/2); burrowed to mottled; greenish gray layer from 9052.2' to 9052.5' with flame structure; burrows; spotty hematite; missing lower contact.

CORE DESCRIPTION
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9057.0 (2760.6)	2.6 (0.8)	SANDSTONE: medium grained, sub-rounded to well rounded; dusky yellow (5Y 6/4); wavy discontinuous sub-parallel laminae; missing lower contact.
9059.6 (2761.4)	1.4 (0.4)	SANDSTONE: medium grained, sub-angular to sub-rounded, moderately well sorted to well sorted; pale yellowish brown (10YR 6/2) and muddy grayish green (5G 5/2); wavy discontinuous sub-parallel laminae; burrows; missing lower contact.
9061.0 (2761.8)	1.0 (0.3)	SANDSTONE: medium grained, sub-rounded to well rounded, well sorted, friable; pale yellowish brown (10YR 6/2); burrowed; burrows, ophiomorpha, skolithos; missing lower contact.
9062.0 (2762.1)	1.8 (0.5)	SANDSTONE: fine to medium grained, sub-rounded, well sorted, friable; grayish green (5G 5/2); burrowed; heavily burrowed, ophiomorpha; spotty hematite; missing lower contact.
9062.8 (2762.3)	3.0 (0.9)	SANDSTONE: fine to medium, well rounded, well sorted, friable; pale yellowish brown (10YR 6/2); heavily burrowed; burrows, skolithos; missing lower contact.

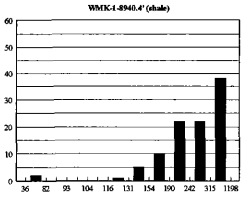
CORE DESCRIPTION
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

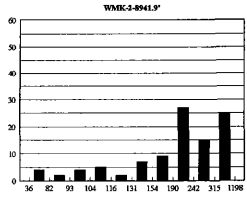
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9065.8 (2763.3)	1.3 (0.4)	SANDSTONE: fine to medium grained, well rounded, well sorted, friable; pale yellowish brown (10YR 6/2) poorly interbedded muddy grayish green (5G 5/2); burrowed; heavily burrowed, ophiomorpha, skolithos; spotty hematite in mud; missing lower contact.
9067.1 (2763.7)	2.9 (0.9)	SANDSTONE: fine to medium grained, well rounded, very well sorted grading to moderately well sorted, becoming muddy near top, friable; pale yellowish brown (10YR 6/2) and muddy grayish green (5G 5/2); burrowed; burrows, ophiomorpha; spotty hematite in top 1'; missing lower contact.
9070.0 (2764.6)	0.2 (0.1)	SHALE: greenish black (5G 2/1); missing lower contact.
9070.2 (2764.6)	2.8 (0.9)	SANDSTONE: medium grained, very well rounded, moderately well sorted, muddy; interbedded wavy continuous to discontinuous parallel muddy greenish black (5G 2/1) to muddy grayish green (5G 5/2) and pale yellowish brown (10YR 6/2) laminae grading to burrowed; burrows near top, skolithos; missing lower contact.
9073.0 (2765.5)	0.7 (0.2)	SANDSTONE: fine grained with some coarse silt, sub-angular, moderately well sorted, very friable; pale yellowish brown (10YR 6/2); massive; missing lower contact.

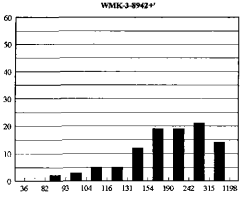
CORE DESCRIPTION
CONOCO Warren McKee #27 (continued)
Warren (McKee) Field
Lea County, New Mexico
T20S, R38E, Section 20
Core: 8940.0-9075.5 feet

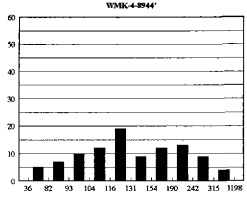
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9073.7 (2765.7)	1.8 (0.5)	SANDSTONE: fine grained with some coarse silt, rounded, poorly sorted, reverse graded; grayish black (N2) sandy silt interbedded with grayish green (5G 5/2) silty sand; wavy discontinuous sub-parallel laminae grading to mottled; some spotty hematite.
9075.5 (2766.2)		END CORE

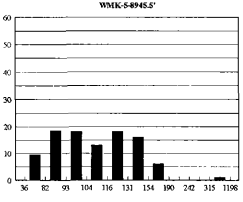
Maximum Entropy Histograms - CONOCO Warren McKee #27

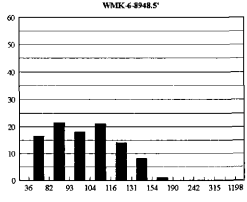




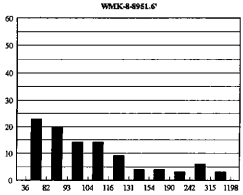


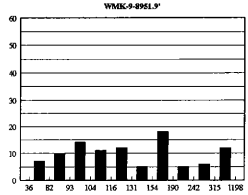


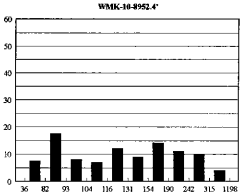


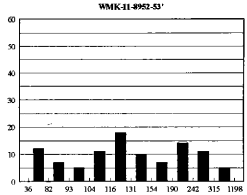


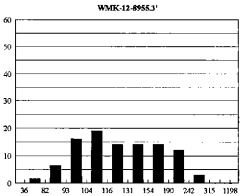
Maximum Entropy Histograms - CONOCO Warren McKee #27 (continued)

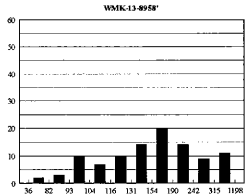




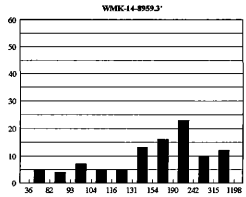


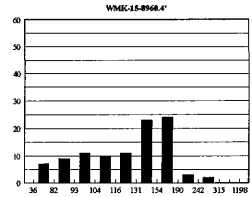


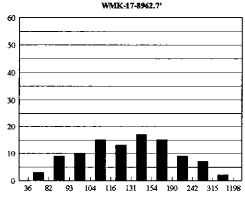


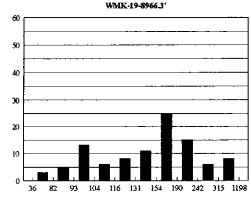


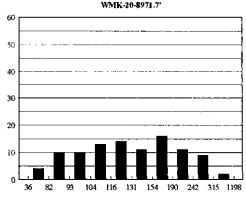
Maximum Entropy Histograms - CONOCO Warren McKee #27 (continued)

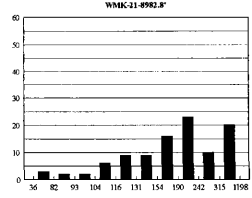




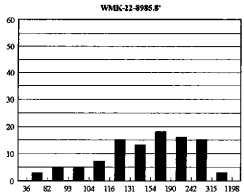


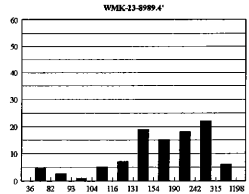


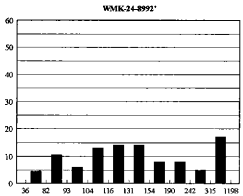


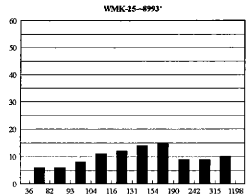


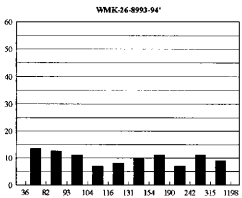
Maximum Entropy Histograms - CONOCO Warren McKee #27 (continued)

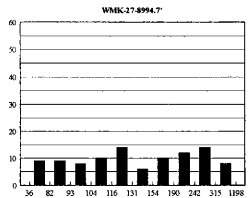




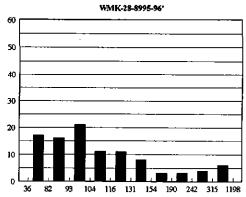


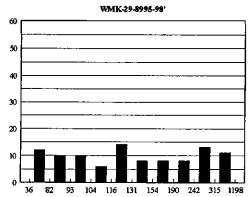


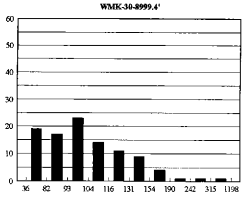


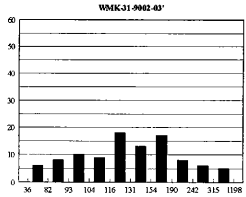


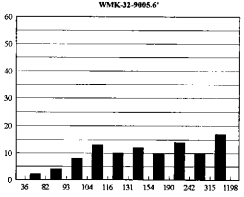
Maximum Entropy Histograms - CONOCO Warren McKee #27 (continued)

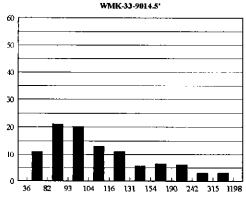




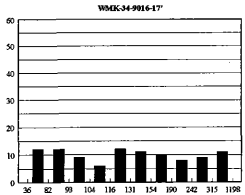


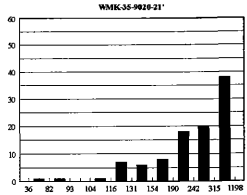


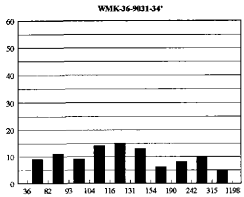


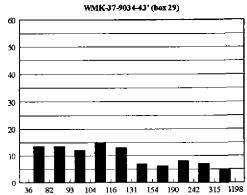


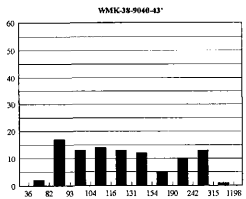
Maximum Entropy Histograms - CONOCO Warren McKee #27 (continued)

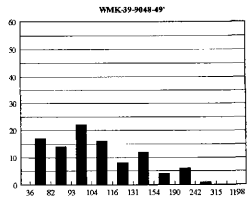




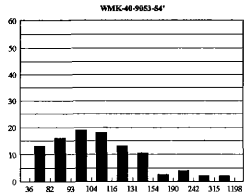


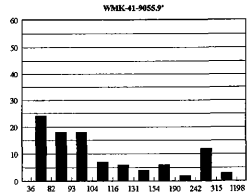


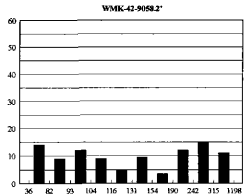


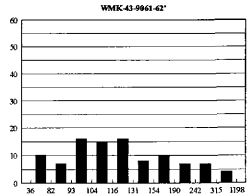


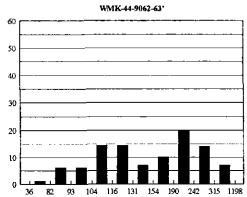
Maximum Entropy Histograms - CONOCO Warren McKee #27 (continued)

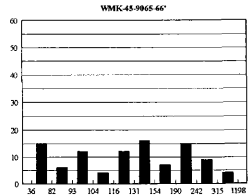




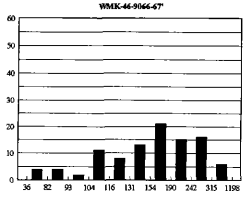


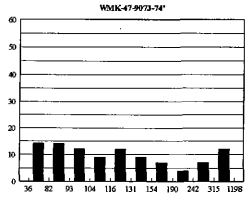






Maximum Entropy Histograms - CONOCO Warren McKee #27 (continued)





GRAIN SIZE ANALYSIS
ARCO University A-11-5
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.

There was no grain size data taken from this core.

PETROGRAPHIC ANALYSIS
ARCO University A-11-5
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

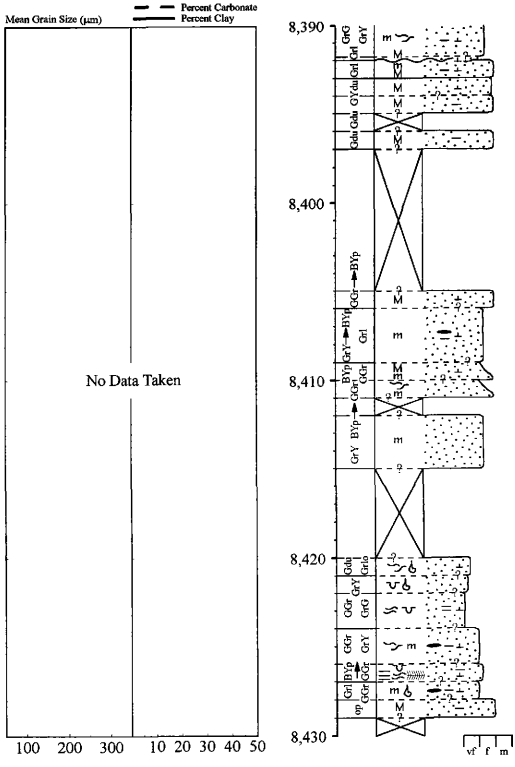
Sample #	Depth (ft.)	Detrital Composition [a]						Authigenic Composition & Porosity [b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %

There were no thin-section billets taken from this core.

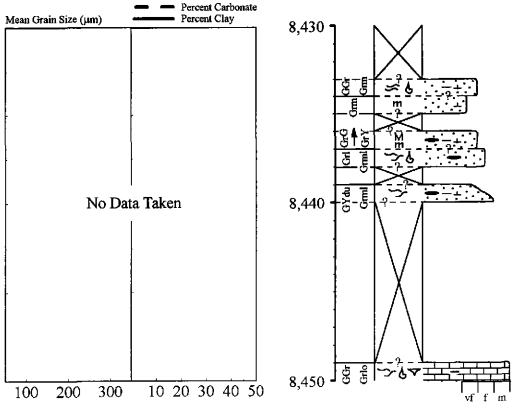
[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

Detailed Graphic Lithology Log - ARCO University A-11-5



Detailed Graphic Lithology Log - ARCO University A-11-5 (continued)



CORE DESCRIPTION
ARCO University A-11-5
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8390.0 (2557.3)	1.8 (0.5)	SANDSTONE: fine to medium grained, sub-rounded to rounded, poorly sorted, calcareous, muddy, friable from bottom to 2/10' from bottom; greenish gray (5G 5/2) and yellowish gray (5Y 8/1); mottled to wavy continuous to discontinuous sub-parallel laminae; burrows, skolithos; sharp lower contact.
8391.8 (2557.8)	0.2 (0.1)	SANDSTONE: fine grained, angular, well sorted, calcareous, well cemented; best fit, light gray (N7); massive; sharp wavy lower contact.
8392.0 (2557.9)	1.0 (0.3)	SANDSTONE: medium grained, rounded, moderately well sorted, calcareous, muddy, friable; best match light gray (N7); more friable massive grading to less friable mottled; sharp planar lower contact.
8393.0 (2558.2)	1.0 (0.3)	SANDSTONE: medium grained, sub-rounded to rounded, moderately well sorted, calcareous, many smaller grains, well-cemented; dusky yellow green (5GY 5/2); massive; missing lower contact.
8394.0 (2558.5)	3.0 (0.9)	SANDSTONE: medium grained, sub-rounded to rounded, poorly sorted to moderately well sorted, muddy, friable; dusky green (5G 3/2); massive; 8395.0' to 8396.0' missing; missing lower contact.
8397.0 (2559.4)	8.0 (2.4)	Missing

CORE DESCRIPTION
ARCO University A-11-5 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8405.0 (2561.8)	1.0 (0.3)	SANDSTONE: medium grained, top 2/10' sub-angular, well sorted and friable; remainder rounded, poorly sorted, and not friable; all calcareous; bottom 2/10' grayish green (10G 4/2), remainder pale yellowish brown (10YR 6/2); massive; sharp lower contact.
8406.0 (2562.1)	3.0 (0.9)	SANDSTONE: fine to medium grained, some very fine, rounded, moderately well sorted, calcareous, more muddy towards bottom, some coarse rock fragments in upper foot; bottom 1' yellowish gray (5Y 7/2) grading to pale yellowish brown (10YR 6/2); mottled with light gray (N7); burrows, skolithos; sharp lower contact.
8409.0 (2563.1)	1.0 (0.3)	SANDSTONE: medium grained grading to fine grained, rounded, moderately well sorted, calcareous; pale yellowish brown (10YR 6/2) to grayish green (5G 5/2); faintly mottled grading to massive; missing lower contact.
8410.0 (2563.4)	1.0 (0.3)	SANDSTONE: medium grained grading to fine grained, rounded, moderately well sorted; faintly mottled pale yellowish brown (10YR 6/2) grading to wavy sub-parallel grayish green (5G 5/2) laminae; missing lower contact.
8411.0 (2563.7)	1.0 (0.3)	MISSING

CORE DESCRIPTION
ARCO University A-11-5 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8412.0 (2564.0)	3.0 (0.9)	SANDSTONE: medium grained with some very fine grained, rounded, moderately well sorted, slightly calcareous; mottled; yellowish gray (5Y 7/2); burrows, skolithos; 8411.0' to 8412.0' missing; missing lower contact.
8415.0 (2564.9)	5.0 (1.5)	MISSING
8420.0 (2566.4)	1.0 (0.3)	SANDSTONE: very fine to fine grained, rounded, poorly sorted in lower 1/2', extremely well sorted in upper 1/2', calcareous in some laminae; dusky green (5G 3/2) and light olive gray (5Y 6/1); wavy discontinuous sub-parallel thin laminae grading to interlaminated light gray (N7) calcareous and dark thick to thin laminae in upper 1/2'; fossiliferous in calcareous laminae, brachiopods; sharp lower contact.
8421.0 (2566.7)	1.0 (0.3)	SANDSTONE: fine grained, sub-angular, moderately well sorted, slightly calcareous, little mud; yellowish gray (5Y 7/2); burrowed; skolithos; fossiliferous, some brachiopods; sharp lower contact.
8422.0 (2567.0)	2.0 (0.6)	SANDSTONE: very fine to coarse silt grained, sub-angular, extremely well sorted, some calcareous laminae, very muddy; interlaminated wavy continuous grayish green (10G 4/2) and calcareous greenish gray (5GY 6/1); some burrows; 1/10' layer of medium sand above 8923.0'; missing lower contact.

CORE DESCRIPTION
ARCO University A-11-5 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8424.0 (2567.6)	2.0 (0.6)	SANDSTONE: very fine to medium grained, rounded, abundant dispersed coarse sand to pea gravel rock fragments, poorly sorted, spotty calcareousness otherwise muddy, sand larger in calcareous sections; greenish gray (10G 4/2) to yellowish gray (5Y 8/1); wavy sub-parallel laminae to mottled; sharp lower contact.
8426.0 (2568.2)	1.0 (0.3)	SANDSTONE: fine to medium with some very fine grained, rounded, moderately well sorted; calcareous pale yellow brown (10YR 6/2) grading to muddy grayish green (10G 4/2); planar to wavy laminae grading to burrowed bedding; 1/20' grayish green (10G 4/2) 1/10' from bottom, cross-lamination below; missing lower contact.
8427.0 (2568.5)	1.0 (0.3)	SANDSTONE: fine grained, some angular coarse sand to pea gravel rock fragments, sub-angular, poorly sorted, calcareous, muddy; mottled light gray (N7) and grayish green (10G 4/2); some fossils; missing lower contact.
8428.0 (2568.9)	1.0 (0.3)	SANDSTONE: medium grained, rounded, poorly sorted, extremely friable (box of sand clumps), some mud; pale olive (10Y 6/2); missing lower contact.
8429.0 (2569.2)	4.0 (1.2)	MISSING

CORE DESCRIPTION
ARCO University A-11-5 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8433.0 (2570.4)	1.0 (0.3)	SANDSTONE: very fine grained, sub-angular, moderately well sorted, calcareous in layers, very muddy in layers, medium grained calcareous sand stringers; wavy continuous parallel muddy dark grayish green (5G 4/1) and calcareous medium gray (N5) laminae; some highly fossiliferous laminae; large flat pyritized clast at top; missing lower contact.
8434.0 (2570.7)	1.0 (0.3)	SANDSTONE: fine to medium grained with some very fine grained, sub-angular, poorly sorted, calcareous; mottled medium gray (N5); missing lower contact.
8435.0 (2571.0)	1.0 (0.3)	MISSING
8436.0 (2571.3)	1.0 (0.3)	SANDSTONE: fine grained, sub-angular, well sorted, calcareous, dense inclined (15 deg.) 1/10' thick layer of grayish black (N2) rounded coarse sand to pea gravel sized mudstone rock fragments at 8436.4'; mottled muddy greenish gray (5GY 6/1) below rock fragments with some burrows; massive yellowish gray (5Y 7/1) above rock fragments; missing lower contact.

CORE DESCRIPTION
ARCO University A-11-5 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8437.0 (2571.6)	1.0 (0.3)	SANDSTONE: fine to medium grained, sub-angular to sub-rounded, poorly sorted, dispersed pea gravel size rock fragments; light gray (N5) and medium light gray (N6); wavy continuous to discontinuous sub-parallel thin laminae; thin laminae of rock fragments near center; fossiliferous, 2 centimeter gastropod near top; missing lower contact.
8438.0 (2571.9)	1.0 (0.3)	MISSING
8439.0 (2572.2)	1.0 (0.3)	SANDSTONE: medium grading to very fine grained, sub-angular to sub-rounded, moderately well sorted, some rounded gravel rock fragments throughout but more near bottom, calcareous but more so in lighter colored laminae, muddier towards top, grayish black (N2) mudstone 3/10' thick in center of section; wavy continuous sub-parallel dusky yellow green (5GY 5/2) and calcareous medium light gray (N6) thin to thick laminae; lower contact missing.
8440.0 (2572.5)	9.0 (2.7)	MISSING
8449.0 (2575.3)	1.0 (0.3)	LIMESTONE: wackestone, fossiliferous, some pellets and shell fragments, abundant brachiopods; grayish green (10G 4/2) and light olive gray (5Y 6/1) interbedded with grayish green (10G 4/2) mudstone; wavy discontinuous sub-parallel thin bedding.

CORE DESCRIPTION
ARCO University A-11-5 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8450.0 (2575.6)		END CORE
REPEATING SECTIONS OF CORE		
8392.0 (2557.9)	1.0 (0.3)	SANDSTONE: fine to medium grained, sub-rounded, moderately well sorted, calcareous, muddy, friable; mottled to massive greenish gray (10G 4/2) grading to best fit pale olive (10Y 6/2).
8393.0 (2558.2)	1.0 (0.3)	SANDSTONE: medium grained, rounded, well sorted, muddy, friable; massive more friable grayish green (5G 5/2) grading to grayish green (10G 5/2).
8406.0 (2562.1)	1.0 (0.3)	SANDSTONE: medium grading to very fine grained, rounded, well sorted, calcareous, muddy; pale yellowish brown (10YR 6/2), greenish gray (5G 5/2), and light gray (N7); faintly mottled grading to mottled grading to wavy discontinuous parallel thin laminae.
8433.0 (2570.4)	1.0 (0.3)	SANDSTONE: medium to coarse grained, sub-rounded to rounded, poorly sorted, more muddy and coarse sand to pea gravel sized rock fragments in near top; mottled grayish green (10G 4/2) and yellowish gray (5Y 7/2), some wavy discontinuous sub-parallel thin laminae.

CORE DESCRIPTION
ARCO University A-11-5 (repeat sections-continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8390.0-8450.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8437.0 (2571.6)	1.0 (0.3)	SANDSTONE: medium grading to very fine grained, sub-rounded to rounded, moderately well sorted, about 10% rock fragments, calcareous very thin bed at top and 1/20' from bottom; light olive gray (5Y 5/2) and dark greenish gray (5GY 4/1) with some light gray (N7); faint wavy discontinuous sub-parallel laminae, otherwise mottled; few fossils.
8439.0 (2572.2)	1.0 (0.3)	SANDSTONE: very fine grained, angular, well sorted, some larger grains, calcareous, medium gray (N5); interbedded with greenish gray (5GY 4/1) mud; wavy sub-parallel very thin beds grading to very thin laminae, becoming less distinctive and more mottled near top.

Maximum Entropy Histograms - ARCO University A-11-5

There was no grain size data taken from this core.

GRAIN SIZE ANALYSIS
ARCO University C-11-3
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8650.0-8673.0 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.
UC-1	8672.9	105.90	90.95	59.98
UC-2	8668.4	107.30	99.11	45.62
UC-3	8665.2	198.82	158.68	137.27
UC-4	8661.0	131.87	110.06	83.67
UC-5	8659.0	130.52	112.23	71.47
UC-6	8657.4	166.22	122.04	119.79
UC-7	8655.6	153.93	130.42	74.69
UC-9	8652.0	125.20	95.66	80.64
UC-10	8661.6	160.23	143.17	87.25

PETROGRAPHIC ANALYSIS
ARCO University C-11-3
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8650.0-8673.0 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
UC-1	8672.9	77 (97)	00 (00)	02 (03)	00 (00)	00 (00)	00 (00)	12	02	00	08
UC-2	8668.4	55 (61)	00 (00)	33 (36)	01 (01)	02 (02)	01 (01)	01	00	08	00
UC-3	8665.2	41 (68)	01 (02)	17 (29)	00 (00)	00 (00)	01 (00)	00	00	37	03
UC-4	8661.0	60 (64)	00 (00)	32 (34)	02 (02)	00 (00)	00 (00)	01	00	01	06
UC-5	8659.0	57 (77)	01 (01)	11 (15)	04 (05)	01 (01)	02 (02)	01	01	19	05
UC-6	8657.4	41 (43)	00 (00)	47 (49)	04 (04)	00 (00)	03 (03)	00	00	02	02
UC-7	8655.6	46 (65)	00 (00)	16 (22)	06 (09)	01 (01)	02 (03)	00	00	28	01
UC-8	8655.2	28 (29)	00 (00)	68 (69)	02 (02)	01 (01)	00 (00)	00	00	01	01

[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

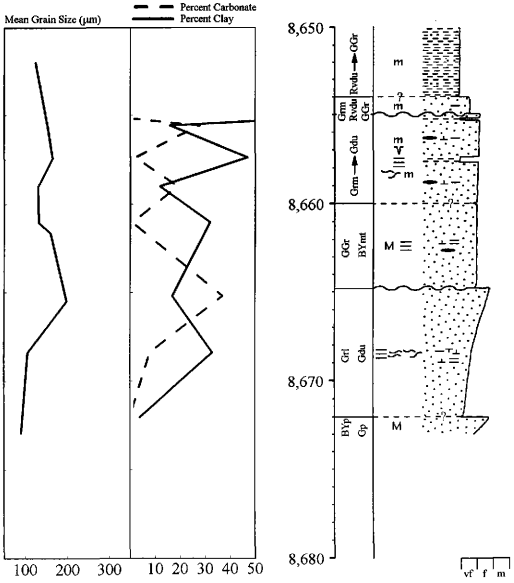
PETROGRAPHIC ANALYSIS (continued)
ARCO University C-11-3
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8650.0-8673.0 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
UC-9	8652.0	40 (41)	00 (00)	56 (58)	02 (02)	00 (00)	00 (00)	00	00	00	02

[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

Detailed Graphic Lithology Log - ARCO University C-11-3



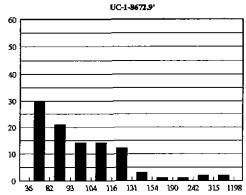
CORE DESCRIPTION
ARCO University C-11-3
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8650.0-8673.0 feet

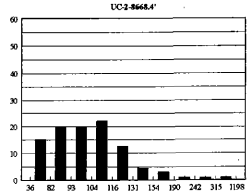
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8650.0 (2636.5)	4.0 (1.2)	SANDSTONE: fine grained, sub-rounded to rounded, very poorly sorted, extremely muddy; mottled very dusky red (10R 2/2) grading to grayish green (5G 5/2); sharp lower contact.
8654.0 (2637.7)	1.0 (0.3)	SANDSTONE: very fine grained with some coarse silt, rounded, moderately well sorted, some mud, slightly calcareous; faintly mottled medium gray (N5) with some very dusky red (10R 2/2) and grayish green (5G 5/2); sharp wavy lower contact.
8655.0 (2638.0)	5.0 (1.5)	SANDSTONE: very fine grained, some coarse silt and fine grained, sub-angular to rounded, very poorly sorted, some rounded calcareous rock fragments and other rock fragments, calcareous, some grading 1/10' thick; medium dark gray (N4) grading to dusky green (5G 3/2), variable friability; wavy discontinuous sub-parallel laminae to mottled; top 1/10' mottled; 8655.1' to 8655.5' planar to wavy continuous parallel laminae; 8655.2' to 8655.3' distinctive grayish brown mudstone with dusky green (5G 3/2) mud drape; mudcracks from 8657.4' to 8657.6'; burrows in bottom 1'; dispersed and laminated dusky green (5G 3/2) mud and spotty light gray (N7) calcareous sand; sharp lower contact.

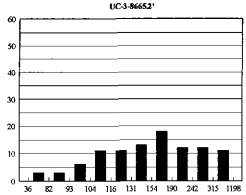
CORE DESCRIPTION
ARCO University C-11-3 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8650.0-8673.0 feet

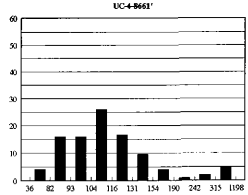
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8660.0 (2639.6)	4.8 (1.5)	SANDSTONE: fine to coarse grained, sub-rounded to rounded, very poorly sorted, coarse rock fragment from base to ½' above; grayish green (10G 4/2) dispersed mud, friable; grayish green (10G 4/2) to moderate yellowish brown (10YR 5/4); massive; planar continuous parallel light gray (N7) calcareous very thin beds from 8661.2' to 8661.4'; 8661.3' much less muddy calcareous concretions with 2/10' thick moderate yellowish brown (10YR 5/4) below; sharp wavy lower contact.
8664.8 (2641.0)	7.2 (2.2)	SANDSTONE: very fine to medium grained, sub-angular to rounded, very poor sorting, extremely calcareous; light gray (N7) sand interbedded with dusky green (5G 3/2) mudstone with very coarse silt and very fine sand; planar to wavy continuous sub-parallel to parallel inclined (5 deg.) laminae; flasers; overall reverse graded, more calcareous sand toward top; some sand lenses in mudstone; sharp lower contact.
8672.0 (2643.2)	1.0 (0.3)	SANDSTONE: very fine grained grading to medium grained, sub-rounded to well rounded, poorly sorted, pale green (10G 6/2) mud in bottom 1/10' and top 2/10'; pale yellowish brown (10YR 6/2); massive.
8673.0 (2643.5)		END CORE

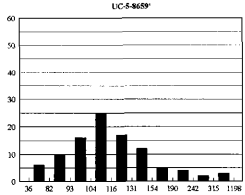
Maximum Entropy Histograms - ARCO University C-11-3

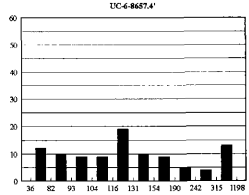




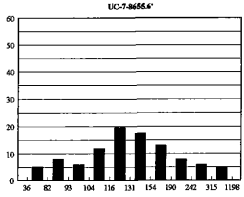


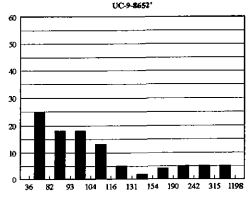


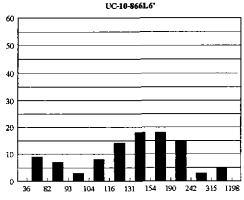




Maximum Entropy Histograms - ARCO University C-11-3 (continued)







GRAIN SIZE ANALYSIS
ARCO University D-11-3
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8361.0-8426.0 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.
UD-2	8418.4	175.33	144.97	96.73
UD-3	8404.8	309.14	272.32	143.06
UD-4	8400.0	200.18	177.43	112.79
UD-5	~8397.0	181.47	147.17	99.34
UD-6	8393.8	160.64	118.53	117.24
UD-7	~8391.5	180.20	142.10	116.48
UD-8	8387.3	174.81	157.02	71.72
UD-9	8386.0	146.14	106.99	108.48
UD-10	8382.8	210.73	166.01	115.48
UD-11	8378.0	265.65	252.94	144.13
UD-12	8373.4	208.94	182.23	110.24
UD-13	8368.5	215.10	190.53	115.15
UD-14	8362.8	109.31	95.38	56.53

PETROGRAPHIC ANALYSIS
ARCO University D-11-3
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8361.0-8426.0 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
UD-1	8423.9	41 (52)	00 (01)	31 (39)	03 (04)	00 (01)	03 (04)	00	00	16	06
UD-2	8418.4	67 (84)	00 (00)	05 (07)	06 (08)	00 (00)	01 (02)	04	03	07	06
UD-3	8404.8	72 (95)	00 (00)	02 (03)	01 (02)	00 (00)	00 (00)	04	04	00	17
UD-4	8400.0	71 (92)	00 (00)	04 (04)	02 (03)	00 (00)	00 (00)	01	01	13	08
UD-5	~8397.0	72 (77)	00 (00)	19 (21)	02 (02)	00 (00)	00 (00)	00	02	00	04
UD-6	8393.8	24 (50)	00 (00)	21 (44)	02 (05)	00 (00)	00 (01)	00	00	50	03
UD-7	~8391.5	20 (21)	00 (00)	68 (74)	02 (02)	01 (01)	01 (01)	00	00	06	01
UD-8	8387.3	58 (70)	00 (00)	16 (20)	04 (05)	01 (01)	01 (01)	00	13	04	00

[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

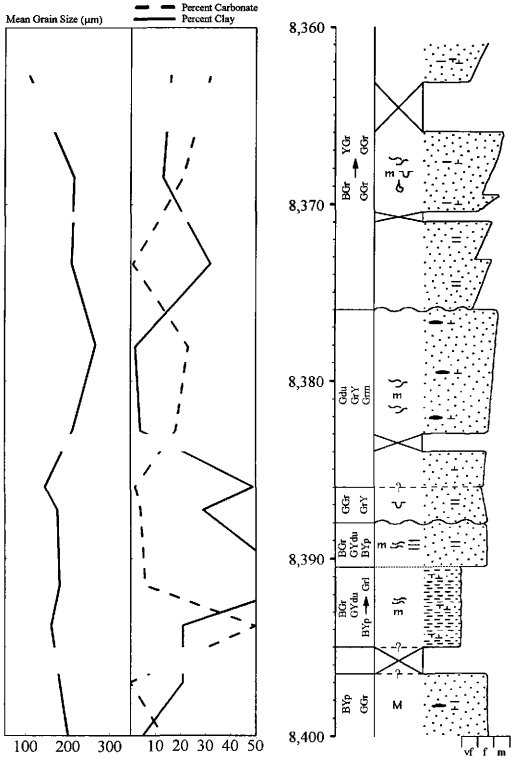
PETROGRAPHIC ANALYSIS
ARCO University D-11-3 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8361.0-8426.0 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
UD-9	8386.0	42 (44)	00 (00)	49 (52)	02 (02)	01 (01)	01 (01)	00	00	02	03
UD-10	8382.8	76 (97)	01 (01)	02 (02)	00 (00)	00 (00)	00 (00)	02	02	18	00
UD-11	8378.1	55 (79)	03 (04)	02 (03)	10 (14)	00 (00)	00 (00)	00	00	23	07
UD-12	8373.4	58 (64)	00 (00)	30 (34)	01 (01)	00 (00)	01 (01)	01	02	01	06
UD-13	8368.5	60 (79)	00 (00)	13 (17)	03 (04)	00 (00)	00 (00)	01	00	21	03
UD-14	8362.8	47 (70)	00 (01)	16 (24)	03 (05)	00 (00)	00 (00)	00	00	32	01

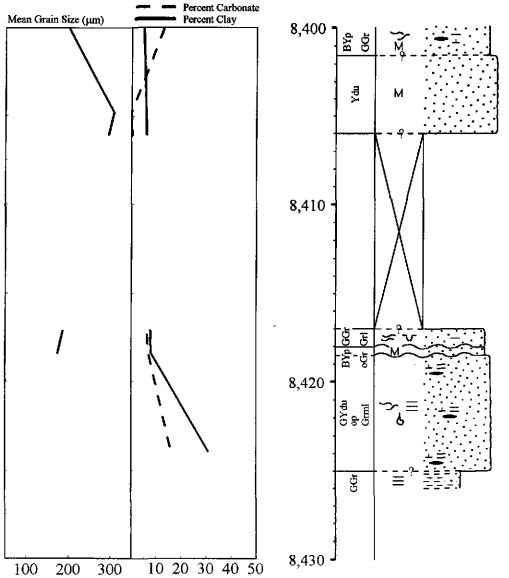
[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

Detailed Graphic Lithology Log - ARCO University D-11-3



Detailed Graphic Lithology Log - ARCO University D-11-3 (continued)



CORE DESCRIPTION
ARCO University D-11-3
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8361.0-8426.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8361.0 (2548.4)	15.0 (4.6)	SANDSTONE: cyclically reverse grading from fine to coarse with breaks at 8363.2', 8367.0', 8369.5', and 8373.2'; some very fine grained, sub-angular, moderately well sorted; interbedded muddy grayish brown (5YR 3/2) and muddy grayish green (10G 4/2) changing to calcareous interbedded yellowish gray (5Y 8/1) and muddy grayish green (10G 4/2); mottled to burrowed; 8362.1' to 8363.0' faint wavy discontinuous sub-parallel laminae, fossils, brachiopods, and a fracture; burrows, skolithos; 8363.2' to 8366.0' and 8370.4' to 8371.0' missing; sharp wavy lower contact.
8376.0 (2553.0)	10.0 (3.0)	SANDSTONE: medium to coarse grained with some fine grained, sub-angular to well rounded, moderately well sorted; mottled muddy extremely friable dusky green (5G 3/2), calcareous friable yellowish gray (5Y 7/2), and some friable calcareous medium gray (N5); 8381.4' to 8381.8' wavy discontinuous sub-parallel laminae; 8383.0' to 8384.0' missing; sharp lower contact.
8386.0 (2556.1)	2.0 (0.6)	SANDSTONE: medium grained with some very fine and fine grained, angular to rounded, poorly sorted, some spotty calcareousness, slightly friable; less muddy grayish green (10GY 5/2) and more muddy dusky brown (5Y 2/1); burrowed; burrows, skolithos; sharp wavy lower contact.

CORE DESCRIPTION
ARCO University D-11-3 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8361.0-8426.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8388.0 (2556.7)	2.5 (0.8)	SANDSTONE: very fine to medium grained, angular to rounded, very poorly sorted, very muddy; mottled muddy grayish brown (5YR 3/2), muddy dusky yellowish green (10G 3/2), and pale yellowish brown (10YR 6/2); some wavy to planar inclined up to 15 deg.; burrows 4/10' from top; gradational lower contact.
8390.5 (2557.4)	4.5 (1.4)	SANDSTONE: medium grained with some coarse silt to coarse grained, angular to well rounded, very poorly sorted, friable, some repeating graded units; muddy grayish brown (5YR 3/2), muddy dusky yellowish green (10G 3/2), and pale yellowish brown (10YR 6/2) grading to muddy grayish brown (5YR 3/2), muddy dusky yellowish green (10G 3/2), and calcareous light gray (N7); mottled grading to calcareous parallel wavy laminae in top 2'; some dusky yellowish green (10G 3/2) mud laminae; burrows, skolithos; larger grains more well rounded; larger grains more frequent in light gray (N7) and pale yellowish brown (10YR 6/2); missing lower contact.
8395.0 (2558.8)	1.5 (0.5)	MISSING
8396.5 (2559.3)	5.1 (1.6)	SANDSTONE: very fine to coarse grained, some pea gravel rock fragments and silt, sub-rounded to well rounded, moderately well sorted; friable pale yellowish brown (10YR 6/2) to very friable grayish green (5G 5/2); massive; wavy laminae from 8401.0' to 8401.4'; missing lower contact.

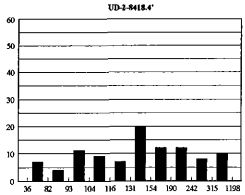
CORE DESCRIPTION
ARCO University D-11-3 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8361.0-8426.0 feet

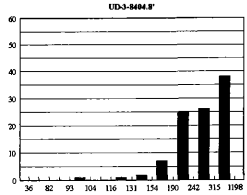
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8401.6 (2560.8)	4.4 (1.3)	SANDSTONE: medium to coarse grained with some fine grained, sub-angular to rounded, well sorted; dusky yellow (5Y 6/4); massive; 1/10' to 2' and larger beds; missing lower contact.
8406.0 (2562.1)	11.0 (3.4)	MISSING
8417.0 (2565.5)	1.0 (0.3)	SANDSTONE: very fine grained with some fine grained and medium grained, rounded to sub-rounded, moderately well sorted, muddy; muddy grayish green (10G 4/2) and calcareous light gray (N7); wavy continuous to discontinuous inclined (5 deg.) laminae; burrows, skolithos; sharp wavy lower contact.
8418.0 (2565.8)	0.5 (0.2)	SANDSTONE: very fine grained with some fine grained and medium grained, sub-angular to sub-rounded, some spotty mud; pale yellowish brown (10YR 6/2) and muddy grayish olive (10Y 4/2); massive; sharp wavy lower contact.

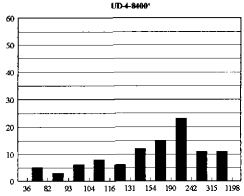
CORE DESCRIPTION
ARCO University D-11-3 (continued)
Martin Field
Andrews County, Texas
T18N, R23W, Section 1 (Block 11)
Core: 8361.0-8426.0 feet

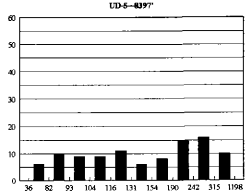
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
8418.5 (2566.0)	6.5 (2.0)	SANDSTONE: medium grained with spotty very fine, graded, medium sub-angular to rounded, very fine angular to sub-rounded, moderately well sorted, calcareous, some mud, friable; dusky yellowish green (10GY 3/2) to pale olive (10Y 6/2) and calcareous medium light gray (N6); wavy sub-parallel inclined up to 30 deg. laminae; one muddy grayish black (N2) planar discontinuous laminae 1/10' from bottom; rip-up clasts near bottom; carbonate crust near top; fossils; sharp lower contact.
8425.0 (2567.9)	1.0 (0.3)	MUDSTONE: grayish green (10G 4/2); very poorly sorted; friable; silty with some angular to sub-rounded very fine and fine grained sand; pyrite, chalcopyrite.
8426.0 (2568.2)		END CORE

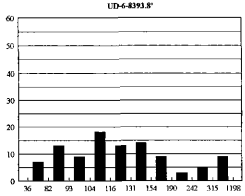
Maximum Entropy Histograms - ARCO University D-11-3

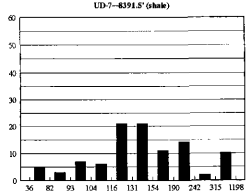




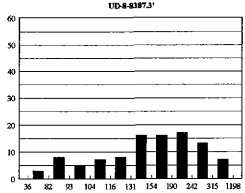


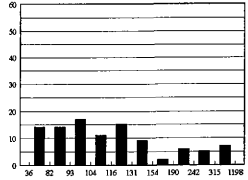


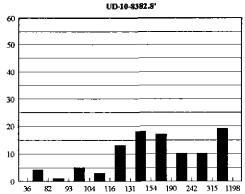


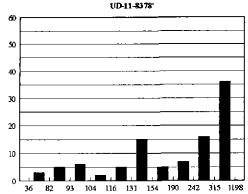


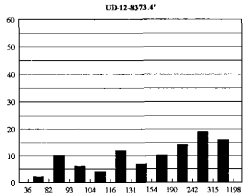
Maximum Entropy Histograms - ARCO University D-11-3 (continued)

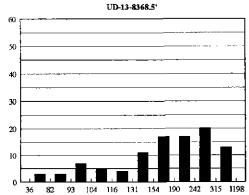




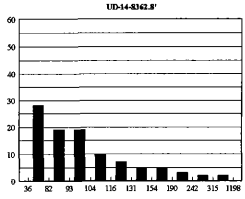








Maximum Entropy Histograms - ARCO University D-11-3 (continued)



GRAIN SIZE ANALYSIS
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.
UB-1	9712.6	226.64	157.14	152.84
UB-2	9712.3	138.55	133.69	41.53
UB-3	9707.0	317.32	300.28	151.44
UB-4	9703.1	319.21	290.39	126.31
UB-5	9700.4	107.21	95.25	40.95
UB-6	9696.0	230.83	241.02	119.15
UB-7	9693.0	208.75	188.42	90.84
UB-8	9690.0	191.38	168.45	107.35
UB-9	9687.0	198.73	187.79	103.22
UB-10	9683.5	199.15	172.95	115.85
UB-11	9681.0	121.64	109.22	49.15
UB-12	9676.8	195.55	182.12	89.46
UB-13	9675.0	170.32	136.67	86.10
UB-14	9673.9	188.67	176.30	75.24
UB-15	9669.0	185.50	155.90	92.66
UB-16	9666.5	233.65	202.98	141.88
UB-17	9665.9	228.09	215.13	118.76
UB-18	9662.7	159.76	98.99	141.83
UB-19	9658.0-9659.0	279.54	266.11	123.26
UB-20	9655.0-9656.0	138.59	114.58	75.69
UB-21	9644.0-9645.0	182.14	170.52	64.01
UB-22	9626.5	223.88	177.20	126.37
UB-23	9624.5	88.56	86.85	19.37
UB-24	~9621.0	129.59	113.84	49.28
UB-25	9618.6	132.19	103.26	83.03
UB-26	9615.0	143.45	141.11	57.35

PETROGRAPHIC ANALYSIS
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
UB-1	9712.6	25 (46)	00 (00)	20 (36)	09 (16)	00 (00)	01 (01)	00	00	42	03
UB-3	9707.0	42 (83)	01 (02)	01 (02)	07 (13)	00 (00)	00 (00)	00	00	50	00
UB-5	9700.4	68 (89)	00 (00)	03 (04)	05 (07)	00 (00)	00 (00)	03	08	10	02
UB-7	9693.0	72 (88)	00 (00)	02 (03)	08 (10)	00 (00)	00 (00)	10	00	10	01
UB-9	9687.0	56 (71)	01 (01)	21 (26)	01 (01)	00 (00)	01 (01)	00	05	15	01
UB-11	9681.0	68 (77)	00 (00)	17 (19)	03 (04)	00 (00)	00 (00)	00	02	05	04
UB-13	9675.0	55 (87)	00 (00)	05 (08)	03 (05)	00 (00)	00 (00)	00	02	29	05
UB-15	9669.0	68 (87)	00 (00)	01 (01)	10 (12)	00 (00)	00 (00)	05	06	08	01

[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

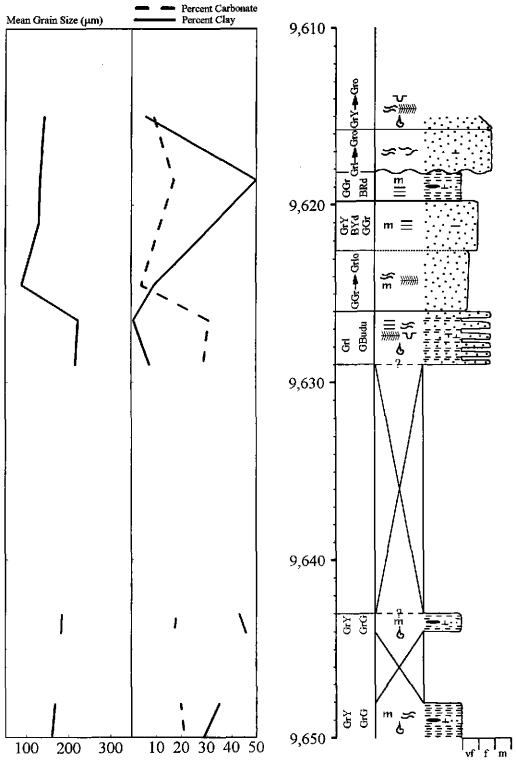
PETROGRAPHIC ANALYSIS
ARCO University B-31-2 (continued)
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
UB-17	9665.9	54 (70)	00 (00)	21 (27)	02 (03)	00 (00)	00 (00)	00	01	22	00
UB-18	9662.7	56 (61)	01 (01)	30 (33)	05 (06)	00 (00)	00 (00)	00	00	07	02
UB-19	9658.0-9659.0	67 (93)	01 (01)	01 (01)	04 (06)	00 (00)	00 (00)	00	00	28	00
UB-21	9644.0-9645.0	33 (40)	01 (01)	47 (58)	01 (02)	00 (00)	00 (00)	00	00	17	01
UB-22	9626.5	65 (95)	00 (00)	00 (00)	03 (05)	00 (00)	00 (00)	00	01	31	01
UB-23	9624.5	76 (89)	00 (00)	04 (04)	05 (05)	00 (00)	01 (01)	05	05	04	02
UB-25	9618.6	31 (38)	01 (01)	50 (60)	01 (01)	00 (00)	01 (01)	00	00	17	00
UB-26	9615.0	72 (97)	00 (00)	02 (03)	01 (01)	00 (00)	00 (00)	09	04	09	03

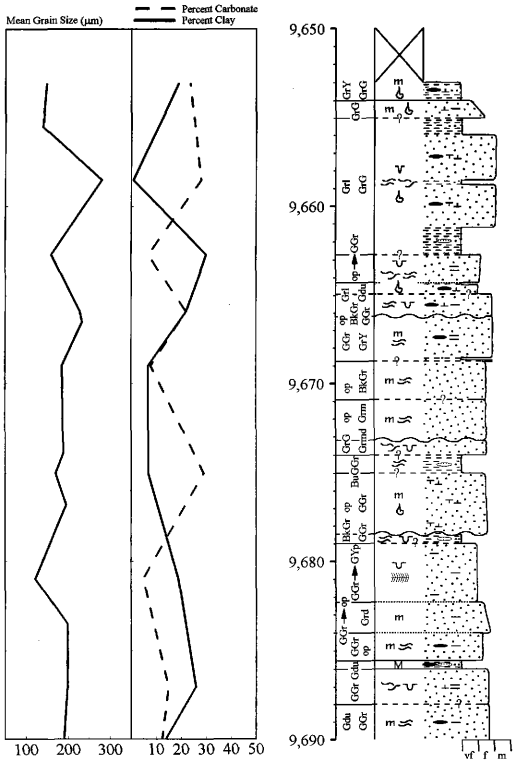
[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

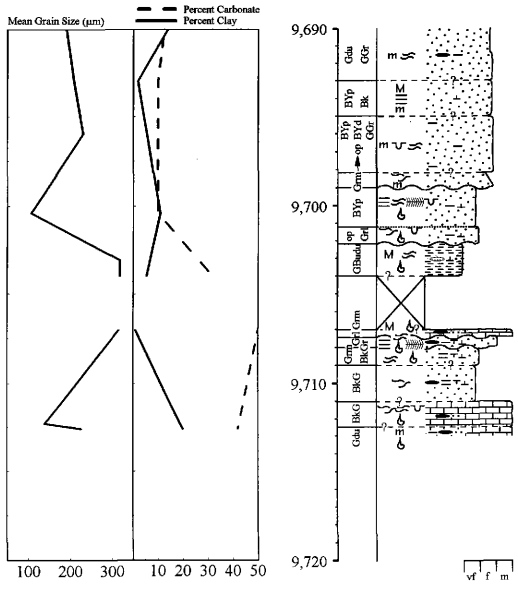
Detailed Graphic Lithology Log - ARCO University B-31-2



Detailed Graphic Lithology Log - ARCO University B-31-2 (continued)



Detailed Graphic Lithology Log - ARCO University B-31-2 (continued)



CORE DESCRIPTION
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9615.0 (2930.7)	0.8 (0.2)	SANDSTONE: fine to medium grained, sub-angular to sub-rounded, grading to sub-angular very fine to fine grained, moderately well sorted, slightly calcareous, muddy in laminae and burrows; yellowish gray (5Y 7/2) grading to olive gray (5Y 4/1); wavy parallel laminae and cross-bedding; mud filled burrows near bottom; few fossils; sharp planar lower contact.
9615.8 (2930.9)	2.4 (0.7)	SANDSTONE: fine to medium grained, rounded, moderately well sorted, top 2/10' very calcareous, otherwise slightly calcareous; best fit light gray (N7) grading to olive gray (5Y 4/1); wavy parallel to sub-parallel muddy laminae; sharp wavy lower contact.
9618.2 (2931.6)	1.6 (0.5)	SANDSTONE: very fine to fine grained with some medium grained, sub-rounded to rounded, moderately well sorted, dispersed fine to very coarse grained rock fragments, muddy; mottled grayish green (5G 5/2) and dark reddish brown (10R 3/4); some planar parallel laminae near bottom; few burrows, skolithos; sharp planar lower contact.
9619.8 (2932.1)	2.8 (0.9)	SANDSTONE: very fine to fine grained with some medium grained, sub-rounded to rounded, moderately well sorted, spotty mud; best fit yellowish gray (5Y 8/1), dark yellowish brown (10YR 4/2), and muddy grayish green (10G 4/2); mottled to planar parallel laminae; some burrows; gradational lower contact.

CORE DESCRIPTION (continued)
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9622.6 (2933.0)	2.4 (0.7)	SANDSTONE: very fine grained to coarse silt, sub-rounded to rounded, very well sorted, slight reverse grading, few beds of fine grained, calcareous, muddy; grayish green (10G 4/2) grading to closest light olive gray (5Y 6/1); mottled grading to wavy continuous parallel laminae; cross-lamination from 9623.3' to 9623.4'; sharp planar lower contact.
9626.0 (2934.0)	3.0 (0.9)	SANDSTONE: interbedded with mudstone; sandstone fine to medium grained, sub-angular to rounded, very well sorted, very calcareous, light gray (N6), cross-bedding in bottom 1', planar to wavy parallel laminae above, very fine grained medium gray (N5) with many fossils from 9628.3' to 9628.9' and some brachiopods, bedding 1/10' to 8/10' thick; mudstone with some very fine grained, slightly calcareous, dusky blue green (5BG 3/2), wavy continuous parallel laminae, bedding 1/20' to 4/10' thick; asymmetric flasers at 9628.1'; burrows in bottom 1/10'; missing lower contact.
9629.0 (2934.9)	14.0 (4.3)	MISSING

CORE DESCRIPTION
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

(continued)

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9643.0 (2939.2)	11.0 (3.4)	SANDSTONE: very fine grained, rounded, very poorly sorted, extremely muddy, very calcareous; rounded medium gray (N5) fossiliferous limestone gravel clasts up to 4 c.m. with sand up to medium grained; mottled sandier yellowish gray (5Y 7/2) and muddier grayish black (N2); wavy 1/20' thick medium gray (N5) fossiliferous limestone laminae at 9649.6' overlain by greenish gray (10G 4/2) micrite; 9644.0' to 9648.0' and 9650.0' to 9653.0' missing; sharp planar lower contact.
9654.0 (2942.5)	1.0 (0.3)	SANDSTONE: medium grained grading to very fine grained, sub-rounded to rounded, moderately well sorted, muddy, very calcareous; mottled grayish green (5G 5/2); burrows, zoophycus; fossils, shells; missing lower contact.
9655.0 (2942.8)	7.7 (2.3)	SANDSTONE: interbedded sandstone and mudstone; sandstone fine to medium grained, rounded to well rounded, very well sorted, some medium grained to gravel rock fragments, very calcareous, light gray (N6) with muddy grayish green (10G 4/2) wavy parallel to sub-parallel laminae, fossils of shell fragments and brachiopods more abundant towards bottom; mudstone, grayish green (10G 4/2), wavy continuous parallel laminae and thin bedding, sandier up to fine grained and mudcracks in top unit, fine to medium grained rounded sand stringers in lower unit; sandstone from 9656.0' to 9658.6' and 9658.8' to 9661.2'. missing lower contact.

CORE DESCRIPTION (continued)
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9662.7 (2945.2)	1.6 (0.5)	SANDSTONE: fine grained and sub-rounded grading to medium grained and rounded, moderately well sorted, slightly calcareous; not as muddy friable pale olive (10Y 6/2) grading to muddier more friable grayish green (10G 4/2); massive; single large horizontal burrow at base; gradational lower contact.
9664.3 (2945.7)	0.6 (0.2)	SANDSTONE: fine to medium grained with abundant very fine grained, sub-rounded to rounded, well sorted, fine to coarse grained rock fragments, all but mud very calcareous; light gray (N7) and dusky green (5G 3/2); wavy discontinuous to continuous sub-parallel to parallel laminae capped by dusky green (5G 3/2) mudstone; fossils, shell fragments, brachiopods; fine to medium grained sand stringers with abundant very fine grained and silt in mudstone; pyrite in mudstone; missing lower contact.
9664.9 (2945.9)	1.3 (0.4)	SANDSTONE: very fine grained with some fine and medium grained, sub-rounded, well sorted, extremely muddy; interlaminated muddy grayish black (N2), muddy grayish green (10G 4/2), and most frequent calcareous pale olive (10Y 6/2) wavy continuous parallel very thin laminae; some asymmetric flasers; single very coarse grained rock fragment; some fine to medium grained sub-rounded sand stringers; one burrow at 9665.6'; abundant pyrite in muddy laminae; sharp wavy lower contact.

CORE DESCRIPTION
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

(continued)

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9666.2 (2946.3)	2.5 (0.8)	SANDSTONE: fine to medium grained with some very fine grained, rounded to well rounded, moderately well sorted, dispersed grayish black (N2) medium grained to pea gravel sized rock fragments, very muddy, spotty calcareousness; mottled grayish green (10G 4/2) and yellowish gray (5Y 7/2); wavy sandy mudstone bed 1/10' to 2/10' from bottom; missing lower contact.
9668.7 (2947.0)	2.2 (0.7)	SANDSTONE: fine to medium grained with abundant very fine grained, sub-rounded to rounded, moderately well sorted, little mud, spotty calcareousness; mottled pale olive (10Y 6/2) and grayish black (N2); few wavy parallel laminae; missing lower contact.
9670.9 (2947.7)	2.3 (0.7)	SANDSTONE: fine to medium grained with abundant very fine grained, sub-rounded to rounded, moderately well sorted, spotty calcareousness; mottled pale olive (10Y 6/2) and medium gray (N4); few wavy parallel laminae; sharp wavy lower contact.
9673.2 (2948.4)	0.8 (0.2)	SANDSTONE: fine grained grading to very fine grained, sub-rounded, well sorted, little mud; wavy discontinuous sub-parallel greenish gray (5GY 6/1) and medium dark gray (N3) laminae; few horizontal burrows; sharp lower contact.

CORE DESCRIPTION
ARCO University B-31-2 (continued)
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9674.0 (2948.6)	1.0 (0.3)	MUDSTONE: grayish blue green (5BG 5/2); few to abundant sub-rounded very fine grained sand; some sub-rounded fine to medium sand stringers; wavy parallel laminae; bottom 2/10' very fine to fine grained sandy mudstone; sharp lower contact.
9675.0 (2948.9)	3.4 (1.0)	SANDSTONE: fine to medium grained some to abundant very fine grained, sub-rounded to rounded, well sorted, slightly calcareous in top 8/10', muddy; mottled pale olive (10Y 6/2) to grayish green (5G 5/2); few fossils, shell fragments; sharp wavy lower contact.
9678.4 (2950.0)	0.6 (0.2)	MUDSTONE: wavy continuous parallel greenish black (5G 2/1) and grayish green (10G 4/2) laminae; some rounded very fine to fine grained sand; some sand stringers containing fine to medium grained sand; burrows; sharp lower contact.
9679.0 (2950.2)	3.3 (1.0)	SANDSTONE: fine to medium grained with some coarse grained, rounded to well rounded, moderately well sorted, slightly calcareous in top 1', muddy especially from 9680.8' to 9681.6', friable; grayish green (10G 4/2) grading to more friable pale yellowish green (10GY 3/2); burrowed; cross-bedding in bottom 8/10'; burrows, skolithos; gradational lower contact.

CORE DESCRIPTION
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

(continued)

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9682.3 (2951.2)	1.7 (0.5)	SANDSTONE: medium grading to fine grained with some very fine and coarse grained, rounded to well rounded, well sorted, slightly calcareous, muddy with less mud upward, friable; grayish green (5G 5/2) grading to sandier pale olive (10Y 6/2) both mottled with dark gray (N3); burrows filled with hydrocarbons; gradational lower contact.
9684.0 (2951.7)	1.5 (0.5)	SANDSTONE: very fine to fine grained with some medium to very coarse grained, sub-rounded to rounded, moderately well sorted, rounded rock fragments smaller up section, muddy; mottled muddy grayish green (10G 4/2) and sandier pale olive (10Y 6/2); one wavy parallel laminae at 9685.0'; sharp planar lower contact.
9685.5 (2952.1)	0.5 (0.2)	MUDSTONE: extremely sandy up to medium grained rounded to well rounded, rock fragments; dusky green (5G 3/2); massive; sand stringers; sharp planar lower contact.
9686.0 (2952.3)	2.0 (0.6)	SANDSTONE: fine to medium grained with much very fine grained, rounded to well rounded, moderately well sorted, some mud mainly in laminae and burrows, slightly friable; grayish green (5G 5/2); wavy discontinuous sub-parallel laminae; skolithos burrows from 9686.3' to 9687.0'; missing lower contact.

CORE DESCRIPTION
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

(continued)

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9688.0 (2952.9)	5.0 (1.5)	SANDSTONE: below 9691.4' well rounded fine to medium grained with some very fine grained and more friable; above 9691.4' rounded very fine to fine grained with some medium and less friable; moderately well sorted, some grayish black (N2) sedimentary rock fragments dispersed throughout, little to no mud in bottom 3/10' grading into much mud; mottled not friable dusky green (5G 3/2) to friable grayish green (10GY 5/2); few wavy parallel laminae, 1/10' to 1' beds; missing lower contact.
9693.0 (2954.4)	2.0 (0.6)	SANDSTONE: fine to medium grained, sub-angular to well rounded, well sorted to very well sorted; pale yellowish brown (10YR 6/2) and black (N1); below 9693.6' mottled with burrows, above 9693.6' planar thick laminae grading to massive; missing lower contact.
9695.0 (2955.0)	3.2 (1.0)	SANDSTONE: fine to medium grained, sub-angular to sub-rounded, moderately well sorted, slightly calcareous, spotty grayish green (10GY 5/2) mud especially in burrows; mottled to burrowed best fit pale yellowish brown (10YR 6/2), dark yellowish brown (10YR 4/2), and grayish green (10GY 4/2); a few wavy parallel thin laminae at 9697.5'; burrows, except in bottom 4/10'; hydrocarbons; missing lower contact.

CORE DESCRIPTION
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

(continued)

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9698.2 (2956.0)	0.8 (0.2)	SANDSTONE: fine to medium grained grading to very fine grained, sub-angular to rounded, moderately well sorted, slightly calcareous; medium gray (N4) hydrocarbon stained sand below burrows, pale olive (10Y 6/2) above; mottled grading to wavy continuous sub-parallel laminae; horizontal burrows 2/10' from bottom; sharp wavy lower contact.
9699.0 (2956.3)	2.2 (0.7)	SANDSTONE: very fine grained with some fine grained, rounded, very well sorted; pale yellowish brown (10YR 6/2); planar to wavy parallel laminae; few wavy parallel very thin sandy mudstone laminae; some cross-bedding; burrows from 9700.1' to 9700.3'; some fossils, shell fragments; gradational lower contact.
9701.2 (2956.9)	1.0 (0.3)	SANDSTONE: very fine to fine grained, sub-angular to rounded, very muddy, pale olive (10Y 6/2), interbedded with light gray (N7) calcareous rounded medium grained, all moderately well sorted; wavy discontinuous laminae and thin bedding; few burrows; some fossils; sharp wavy lower contact.
9702.2 (2957.2)	1.8 (0.5)	MUDSTONE: dusky blue green (5BG 3/2); abundant rounded to well rounded very fine to medium grained; massive to wavy parallel laminae; calcareous sub-rounded to rounded fine to medium grained light gray (N6) sand stringers containing few fossils; missing lower contact.

CORE DESCRIPTION
ARCO University B-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

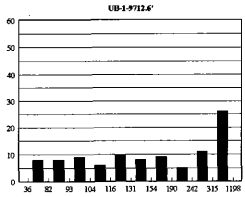
(continued)

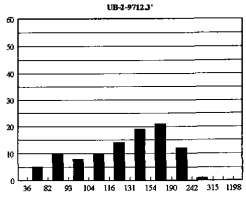
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9704.0 (2957.8)	3.0 (0.9)	MISSING
9707.0 (2958.7)	0.4 (0.1)	LIMESTONE: wackestone; abundant (~20%) rounded fine to medium grained sand, some very coarse rock fragments; medium gray (N5); massive; fossils, shell fragments; sharp wavy lower contact.
9707.4 (2958.8)	0.6 (0.2)	SANDSTONE: medium to coarse grained, abundant rounded very coarse grained and gravel rock fragments, sub-rounded to rounded, poorly sorted, extremely calcareous; light gray (N7); planar parallel laminae and cross-bedding; wavy medium gray (N5) mudstone laminae in top 1/10'; fossils, shell fragments; sharp wavy lower contact.
9708.0 (2959.0)	1.0 (0.3)	SANDSTONE: very fine to fine grained, sub-rounded, moderately well sorted, medium gray (N5), interlaminated with grayish black (N2) sandy mudstone; some well rounded medium grained very thin laminae near mudstone fringes; all calcareous; wavy continuous parallel laminae; fossiliferous; missing lower contact.
9709.0 (2959.3)	2.0 (0.6)	SANDSTONE: very fine grained, sub-rounded, well sorted, abundant medium gray (N5) rounded calcareous gravel rock fragments, very muddy, very calcareous; greenish black (5G 2/1); wavy sub-parallel laminae; missing lower contact.

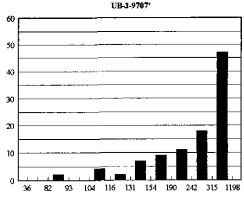
CORE DESCRIPTION
ARCO University B-31-2 (continued)
Block 31 Field
Crane County, Texas
T12N, R20W, Section 40
Core: 9615.0-9713.0 feet

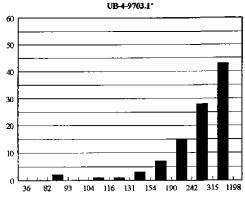
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9711.0 (2959.9)	1.5 (0.5)	LIMESTONE: wackestone; abundant (~20%) rounded very fine to fine grained sand, rounded calcareous gravel rock fragments from base to 1' above; medium gray (N5); wavy parallel and sub-parallel greenish black (5G 2/1) sandy mudstone laminae; burrows; fossils, abundant shell fragments; missing lower contact.
9712.5 (2960.4)	0.5 (0.2)	SANDSTONE: medium grained, rounded to well rounded, poorly sorted, coarse grained to gravel calcareous light gray (N7) mudstone rock fragments, very muddy, calcareous, friable; dusky green (5G 3/2); mottled; some burrows; some fossils.
9713.0 (2960.5)		END CORE DESCRIPTION

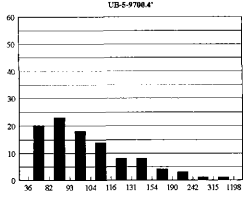
Maximum Entropy Histograms - ARCO University B-31-2

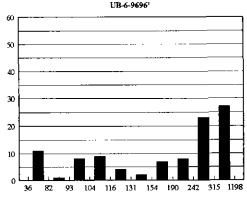




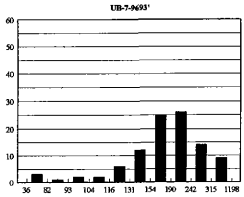


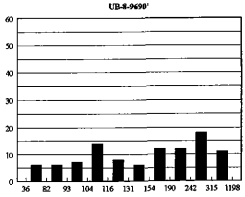


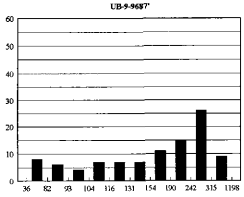


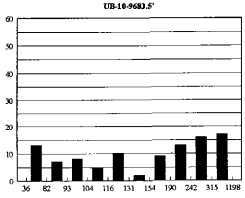


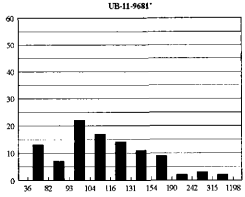
Maximum Entropy Histograms - ARCO University B-31-2 (continued)

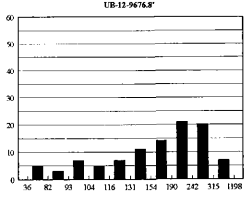




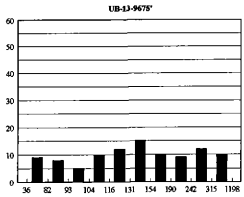


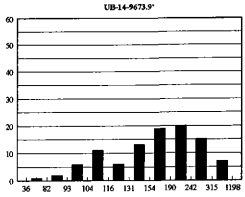


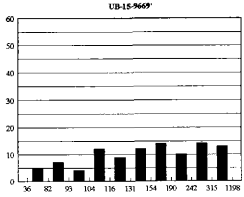


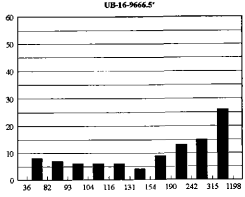


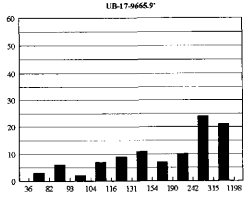
Maximum Entropy Histograms - ARCO University B-31-2 (continued)

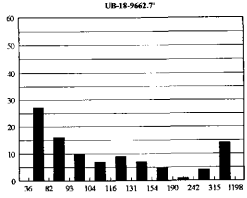




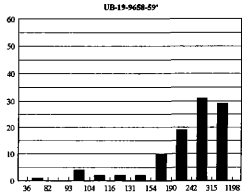


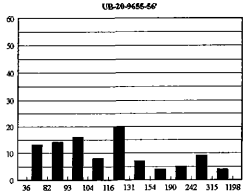


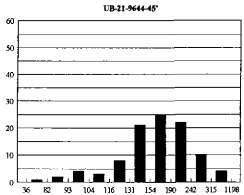


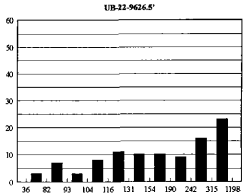


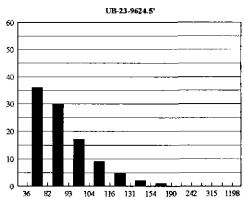
Maximum Entropy Histograms - ARCO University B-31-2 (continued)

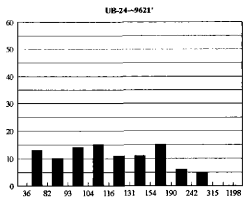




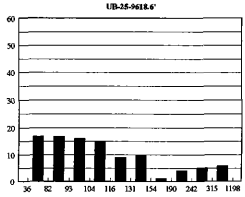


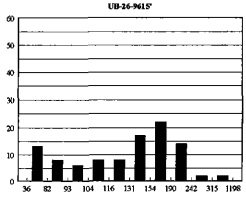






Maximum Entropy Histograms - ARCO University B-31-2 (continued)





GRAIN SIZE ANALYSIS
ARCO University PL-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 33
Core: 9688.0-9734.0 feet

Sample #	Depth (ft.)	Long Axis Length (microns)		
		Mean	Median	Std. Dev.
UPL-3	9703.0	157.52	120.29	88.26
UPL-4	9700.0-9710.0	277.91	277.91	106.87
UPL-5	9707.7	188.49	170.78	71.67
UPL-6	9697.0	263.03	242.84	154.08
UPL-7	9690.0	281.45	248.11	147.22

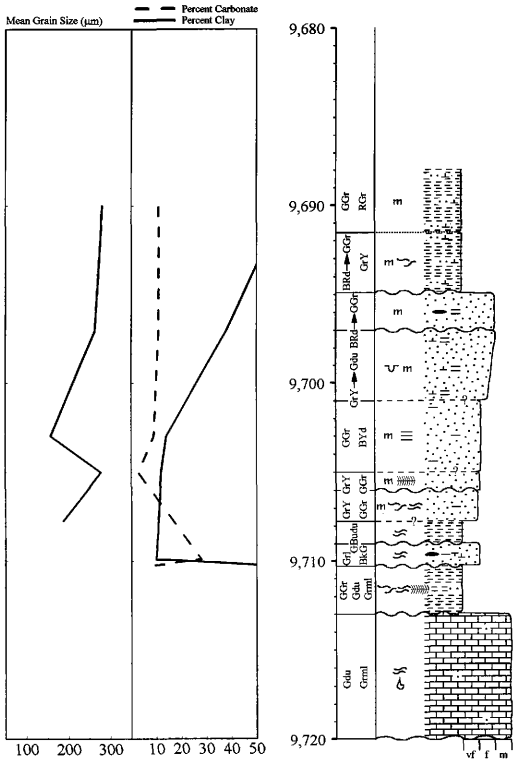
PETROGRAPHIC ANALYSIS
ARCO University PL-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 33
Core: 9688.0-9734.0 feet

Sample #	Depth (ft.)	Detrital Composition[a]						Authigenic Composition & Porosity[b]			
		Qtz % (N)	Rf % (N)	Clay % (N)	Col % (N)	Fos % (N)	Other % (N)	Qog %	Clay %	Car %	Por %
UPL-1	9710.3	34 (36)	00 (00)	59 (63)	00 (00)	00 (00)	01 (01)	00	00	06	00
UPL-2	9709.9	57 (82)	00 (00)	08 (12)	02 (03)	02 (02)	00 (00)	00	02	28	01
UPL-3	9703.0	67 (87)	00 (00)	07 (10)	03 (03)	00 (00)	00 (00)	06	07	09	01
UPL-4	9700.0-9710.0	74 (85)	00 (00)	00 (00)	01 (02)	00 (00)	00 (00)	01	12	03	09
UPL-6	9697.0	49 (55)	00 (01)	38 (43)	01 (02)	00 (00)	00 (00)	00	00	11	00
UPL-7	9690.0	27 (30)	00 (00)	61 (68)	00 (00)	00 (00)	01 (01)	00	00	11	00

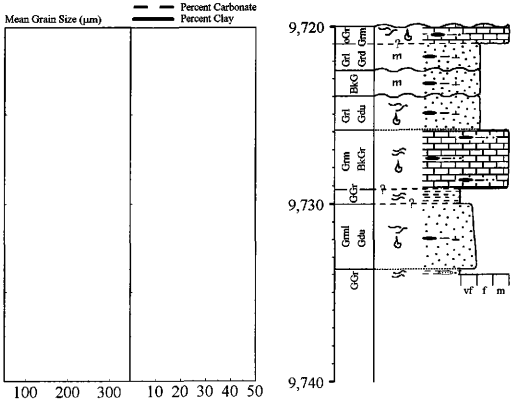
[a] Qtz = monocrystalline and polycrystalline quartz, Rf = rock fragments, Col = collophane, Fos = fossils, % = percent of total composition, N = normalized to 100 % of detrital composition.

[b] Qog = quartz overgrowth, Car = carbonates, Por = porosity.

Detailed Graphic Lithology Log - ARCO University Pl-31-2



Detailed Graphic Lithology Log - ARCO University Pl-31-2 (continued)



CORE DESCRIPTION
ARCO University PL-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 33
Core: 9688.0-9734.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9688.0 (2952.9)	3.6 (1.1)	SANDSTONE: very fine to medium grained, sub-rounded to well rounded, poorly sorted, very muddy especially near bottom, calcareous light gray (N7) sand in burrows near top; in top 1' mottled grayish green (10GY 5/2), grayish red (10R 4/2), and light gray (N7); below top 1' mottled grayish green (10GY 5/2) and grayish red (10R 4/2); burrows in top 1', skolithos; gradational lower contact.
9691.6 (2954.0)	3.3 (1.0)	MUDSTONE: abundant very fine to medium grained grading to muddy very fine to medium grained sub-rounded to rounded poorly sorted sandstone at 9693.1'; mottled dark reddish brown (10R 3/4) and calcareous yellowish gray (5Y 8/1) changing to mottled grayish green (10G 4/2) and calcareous yellowish gray (5Y 8/1) at 9693.6'; some faint wavy sub-parallel laminae; sharp wavy lower contact.
9694.9 (2955.0)	2.1 (0.6)	SANDSTONE: very fine to medium grained, sub-rounded to well rounded, poorly sorted, abundant medium grained to gravel rock fragments, muddy; mottled dark reddish brown (10R 3/4) grading to grayish green (10G 4/2); burrows in upper 1', grayish green (10G 4/2) and slightly calcareous yellowish gray (5Y 8/1) burrow fill; diagenetic structures dark reddish brown (10R 3/4) with grayish green (10G 4/2) rim, or visa versa; sharp wavy lower contact.

CORE DESCRIPTION (continued)
ARCO University PL-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 33
Core: 9688.0-9734.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9697.0 (2955.6)	4.0 (1.2)	SANDSTONE: very fine grained with some fine and medium grained, medium grained amount increasing towards top, sub-angular to rounded, poorly sorted; calcareous yellowish gray (5Y 7/2) grading to muddy and slightly calcareous grayish green (5G 5/2) grading to very muddy dusky green (5G 3/2); burrowed to mottled; burrows, skolithos 1' long burrows in center; missing lower contact.
9701.0 (2956.9)	4.0 (1.2)	SANDSTONE: very fine to medium grained, sub-rounded to rounded, moderately well sorted, some spotty calcareousness, slightly friable; mottled grayish green (5G 5/2) and dark yellowish brown (10YR 4/2) to black (N1) hydrocarbons; some planar continuous parallel laminae; very broken up and possibly mislabeled; missing lower contact.
9705.0 (2958.1)	1.0 (0.3)	SANDSTONE: fine grained with abundant very fine grained, sub-rounded to rounded, moderately well sorted, very slightly calcareous; mottled yellowish gray (5Y 7/2) with some muddy grayish green (10G 4/2); cross-bedding from 9705.1' to 9705.2'; dewatering structures from 9705.5' to 9705.6'; sharp wavy lower contact.
9706.0 (2958.4)	1.7 (0.5)	SANDSTONE: very fine grained, sub-rounded, very well sorted; calcareous yellowish gray (5Y 7/2) and muddy grayish green (10G 4/2); mottled to discontinuous to continuous sub-parallel to parallel laminae; flasers and dewatering structure in bottom ½'; sharp wavy lower contact.

CORE DESCRIPTION (continued)
ARCO University PL-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 33
Core: 9688.0-9734.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9707.7 (2958.9)	1.3 (0.4)	MUDSTONE: dusky blue green (5BG 3/2); very little sub-angular medium grained and below sand; wavy parallel laminae; sharp wavy lower contact.
9709.0 (2959.3)	1.3 (0.4)	SANDSTONE: fine to medium grained, sub-rounded to rounded, moderately well sorted, rock fragments, calcareous; best fit light gray (N7); interbedded with sandy best fit greenish black (5GY 2/1) mudstone, very fine and fine grained; wavy discontinuous parallel laminae; sharp wavy lower contact.
9710.3 (2959.7)	2.7 (0.8)	SANDSTONE: very fine grained, sub-rounded, well sorted, calcareous; interlaminated muddy grayish green (10G 4/2) to muddy dusky green (5G 3/2) and calcareous medium light gray (N6); wavy discontinuous to continuous sub-parallel to parallel very thin laminae; cross-lamination; flasers; dewatering structures; sharp wavy lower contact.
9713.0 (2960.5)	7.0 (2.1)	LIMESTONE: wackestone; some sub-angular very fine sand; fossiliferous; dusky green (5G 3/2); some medium light gray (N6) 1 c.m. to 3 c.m. more fossiliferous beds; wavy continuous parallel laminae; sharp wavy lower contact.

CORE DESCRIPTION (continued)
ARCO University PL-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 33
Core: 9688.0-9734.0 feet

Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9720.0 (2962.7)	1.0 (0.3)	LIMESTONE: wackestone; some sub-rounded very fine to coarse sand, very fossiliferous, muddy, calcareous concretions or gravel clasts containing very fine to fine grained sand; muddy grayish olive (10Y 4/2) and medium gray (N5); wavy discontinuous sub-parallel laminae; missing lower contact.
9721.0 (2963.0)	1.6 (0.5)	SANDSTONE: very fine to medium grained, sub-rounded to rounded, poorly sorted, calcareous, calcareous concretions or gravel clasts in bottom 3/10'; mottled best fit light gray (N7) and very muddy best fit dark gray (N3); sharp wavy lower contact.
9722.6 (2963.4)	1.4 (0.4)	SANDSTONE: very fine to fine grained, sub-angular to sub-rounded, poorly sorted, medium gray (N5) very calcareous concretions or clasts of all sizes, muddy, calcareous; greenish black (5G 2/1); mottled; sharp wavy lower contact.
9724.0 (2963.9)	1.9 (0.6)	SANDSTONE: fine to medium grained, sub-rounded to rounded, poorly sorted, medium light gray (N6) and muddy dusky green (5G 3/2) rounded rock fragments, calcareous; light gray (N6) and muddy dusky green (5G 3/2); wavy discontinuous sub-parallel laminae; many fossils, brachiopods; gradational lower contact.

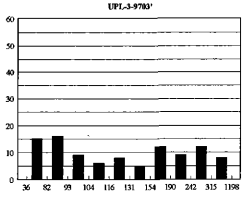
CORE DESCRIPTION (continued)
ARCO University PL-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 33
Core: 9688.0-9734.0 feet

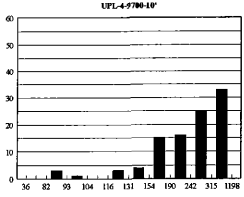
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9725.9 (2964.5)	3.3 (1.0)	LIMESTONE: wackestone; very abundant sub-angular to sub-rounded very fine to fine grained sand with some rounded to well rounded medium grained especially near top, 1 c.m. to 3 c.m. rounded calcareous rock fragments, variable amounts of mud; medium gray (N5) and muddy best fit grayish black (N2); wavy continuous parallel laminae; abundant fossils, brachiopods; missing lower contact.
9729.2 (2965.5)	0.8 (0.2)	MUDSTONE: grayish green (10G 4/2); some dispersed well rounded very fine to medium grained; wavy continuous parallel laminae; broken up; missing lower contact.
9730.0 (2965.7)	3.7 (1.1)	SANDSTONE: very fine grained, graded, sub-rounded, poorly sorted, locally abundant well rounded fine and medium grained, some mudstone rock fragments graded up to very coarse grained near top, calcareous rock fragments abundant in top 1.4'; very calcareous medium light gray (N6) and very muddy dusky green (5G 3/2); wavy discontinuous to continuous sub-parallel laminae to thin bedding; fossils in calcareous medium light gray (N6) beds, brachiopods; pyrite; gradational lower contact.
9733.7 (2966.8)	0.3 (0.1)	MUDSTONE: grayish green (10G 4/2); some dispersed sub-rounded to rounded very fine to medium grained, some medium grained lenses; wavy continuous parallel thick laminae to thin bedding; mud ball extending into upper unit; pyrite.

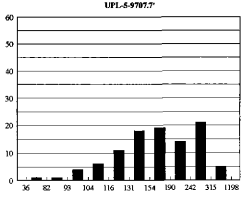
CORE DESCRIPTION (continued)
ARCO University PL-31-2
Block 31 Field
Crane County, Texas
T12N, R20W, Section 33
Core: 9688.0-9734.0 feet

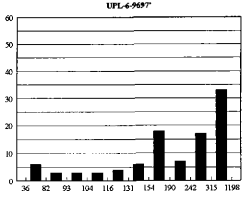
Depth (ft.) (m.)	Thickness (ft.) (m.)	Description
9734.0 (2966.9)		END CORE DESCRIPTION

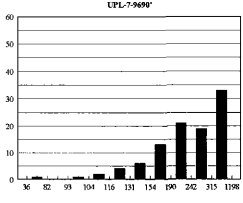
Maximum Entropy Histograms - ARCO University PL-31-2











VITA

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